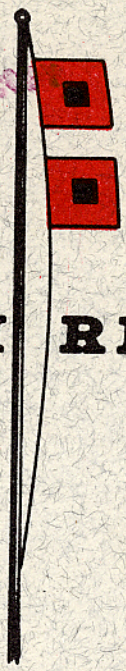
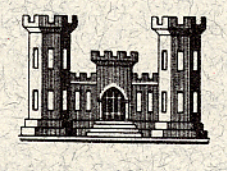
HURRICANE SURVEY



INTERIM REPORT

STAMFORD

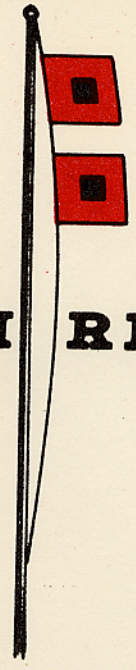
CONNECTICUT



U.S. Army Engineer Division, New England
Corps of Engineers
Boston, Mass.

8 APRIL 1958

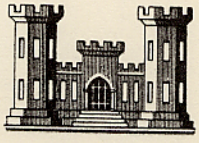
HURRICANE SURVEY



INTERIM REPORT

STAMFORD

CONNECTICUT



U.S. Army Engineer Division, New England
Corps of Engineers
Boston, Mass.

8 APRIL 1958

ARMY-NED-BOSTON

SYLLABUS

The Division Engineer finds that a serious problem of hurricane tidal flooding exists in the city of Stamford, Connecticut, particularly in the highly industrialized area of the South End between the East and West Branches at the head of Stamford Harbor. The acuteness of the problem is indicated by the fact that three severe hurricanes and two other great storms have struck the city in the past 20 years and, upon their recurrence, would cause total flood damages of over $11,000,000 at 1957 prices. Average annual damages from tidal flooding amount to $378,000.

The Division Engineer recommends, for the protection of Stamford, Connecticut, the construction of a rock-faced, earth-filled barrier across the East Branch, with dike extensions on both banks, and a gated opening for navigation; dike and wall protection along the east bank of the West Branch; dike protection in the Westcott Cove-Cummings Park area of the city; and other appurtenant structures. The estimated first cost is $5,586,000, of which $3,030,000 is to be born by the United States and $2,556,000 by local interests.

R. 2-9-59

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GLOSSARY

HURRICANE SURGE: the mass of water causing an increase in elevation of the water surface above predicted astronomical tide at the time of a hurricane; it includes wind setup; sometimes the maximum increase in elevation is referred to as the surge.

HURRICANE TIDE: the rise and fall of the water surface during a hurricane, exclusive of wave action.

KNOT: a velocity equal to one nautical mile (6080.2 ft.) per hour (about 1.15 statute miles per hour).

OVERTOPPING: that portion of the wave runup which goes over the top of a protective structure.

PONDING: the storage of water behind a dike or wall from local runoff and/or overtopping by waves.

POOL BUILDUP: the increase in elevation of water surface behind a structure due to runoff and/or overtopping by waves.

RUNUP: the rush of water up the face of a structure on the breaking of a wave. The height of runup is measured from the stillwater level.

SIGNIFICANT WAVE: a statistical term denoting waves with the average height and period of the one-third highest waves of a given wave train.

SPRING TIDE: a tide that occurs at or near the time of new and full moon and which rises highest and falls lowest from the mean level.

STILLWATER LEVEL: the elevation of the water surface if all wave action were to cease.

STORM SURGE: same as "hurricane surge."

WAVE HEIGHT: the vertical distance between the crest and preceding trough

WAVE TRAIN: a series of waves from the same direction.

WIND SETUP: the vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
150 CAUSEWAY STREET
BOSTON 14, MASS.

8 April 1958

SUBJECT: Interim Report on Hurricane Survey, Stamford, Connecticut

TO: Chief of Engineers
Department of the Army
Washington, D. C.
ATTENTION: ENGWF

AUTHORITY

1. This report is submitted in compliance with Public Law 71, Eighty-fourth Congress, First Session, approved 15 June 1955, which reads as follows:

> "Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in view of the severe damage to the coastal and tidal areas of the eastern and southern United States from the occurrence of hurricanes, particularly the hurricanes of August 31, 1954, and September 11, 1954, in the New England, New York, and New Jersey coastal and tidal areas, and the hurricane of October 15, 1954, in the coastal and tidal areas extending south to South Carolina, and in view of the damages caused by other hurricanes in the past, the Secretary of the Army, in cooperation with the Secretary of Commerce and other Federal agencies concerned with hurricanes, is hereby authorized and directed to cause an examination and survey to be made of the eastern and southern seaboard of the United States with respect to hurricanes, with particular reference to areas where severe damages have occurred.
>
> "SEC. 2. Such Survey, to be made under the direction of the Chief of Engineers, shall include

the securing of data on the behavior and frequency of hurricanes, and the determination of methods of forecasting their paths and improving warning services, and of possible means of preventing loss of human lives and damages to property, with due consideration of the economics of proposed breakwaters, seawalls, dikes, dams, and other structures, warning services, or other measures which might be required."

SCOPE OF SURVEY

2. SCOPE

This interim report of survey scope presents the results of an examination and survey of hurricane and other storm-induced tidal flooding in the city of Stamford, Connecticut. It is one in a series of reports which, when completed, will constitute a survey of the entire coastal area of New England subject to tidal flooding occasioned by hurricanes and other great storms.

This report includes data on climatology, hydrology, and tidal-flood damages; a summary of the historical occurrences of hurricanes and other severe storms; and a description, together with estimates of costs and benefits, of a recommended plan of improvement which will provide protection against tidal flooding.

Field work has consisted of flood damage investigations, topographic and hydrographic surveys in the area of considered protective works, and subsurface explorations to determine the nature and characteristics of underlying material.

3. COORDINATION

State officials and local interests have been consulted frequently during the course of the study and the work has been coordinated and discussed with appropriate Federal agencies. The views of local interests were considered in arriving at a practicable and economic means of providing needed protection. A public hearing has been held to acquaint all interested parties with the recommended plan of protection and to obtain their views and comments thereon. Coordination with other agencies is discussed in further detail in paragraph 83.

PRIOR REPORTS

4. HURRICANE REPORTS

There are no previous reports by the Corps of Engineers on the specific subject of hurricane protection for the city of Stamford. Part Two, Chapter XXXIX (unpublished) of the report (Senate Document

No. 14, 85th Congress, First Session), on the "Land and Water Resources of the New England-New York Region", prepared by the New England-New York Inter-Agency Committee, pursuant to Presidential directive of October 9, 1950, includes a brief history of hurricane occurrences in New England, a description and summary of experienced losses in recent hurricanes, and a discussion of several methods of reducing damages.

5. NAVIGATION REPORTS

a. Stamford Harbor. Stamford Harbor has been the subject of many unpublished navigation reports since 1830, and published reports since 1882. The following four reports form the basis for the existing navigation project:

(1) House Document No. 1130, 63rd Congress, Second Session, 1914.

(2) River and Harbor Committee Document No. 8, 74th Congress, First Session, 1934.

(3) River and Harbor Committee Document No. 29, 75th Congress, First Session, 1937.

(4) River and Harbor Committee Document No. 676, 79th Congress, Second Session, 1946.

b. Westcott Cove. Westcott Cove has been the subject of two unpublished navigation reports: a preliminary examination report submitted in 1936 and a survey report submitted in 1940. A favorable report submitted in 1947 - River and Harbor Committee Document No. 379, 80th Congress, First Session - forms the basis for authorization of the existing project.

6. BEACH EROSION CONTROL REPORTS

House Document No. 174, 85th Congress, First Session, containing a Beach Erosion Control Study on Areas 8 and 11, Saugatuck River to Byram River, Connecticut, recommends that the United States adopt projects authorizing Federal participation in the construction of protective works at a number of Connecticut coastal areas, including two at Stamford.

DESCRIPTION

7. LOCATION AND EXTENT OF AREA

The city of Stamford, Connecticut, is located in Fairfield County, on the north shore of Long Island Sound, approximately 30 miles east

of New York City and 20 miles southwest of Bridgeport, Connecticut. It is adjacent to the towns of Darien on the east and Greenwich on the west. Stamford covers an area of nearly 40 square miles and it has a total waterfrontage of approximately 15 miles along the tidal portions of Stamford Harbor, Long Island Sound, Westcott Cove, Cove Harbor, and Holly Pond.

8. HARBOR AND OTHER WATER AREAS

The waters adjacent to Stamford include Stamford Harbor and its Branches, Westcott Cove, Cove Harbor, and Holly Pond. They are briefly described below.

a. Stamford Harbor. The main harbor at Stamford is an indentation of Long Island Sound, extending inland about 1.5 miles, between Shippan Point on the east and the mainland on the west. Two breakwaters separate the harbor from Long Island Sound. The harbor varies in width from about 1.5 miles at its outer end, off the southern end of Shippan Point, to about 0.6 mile at its inner end where it is joined by the East and West Branches. The East Branch is a narrow tidal creek that extends north about 1.5 miles. The West Branch, about 1.25 miles long, is the tidal portion of the Rippowam River which flows from the north. Improved channels for navigation have been provided through the main harbor and up both of the Branches. Information on the existing navigation project for Stamford Harbor and the controlling depths in the improved waterways are contained in paragraph 50. The principal commercial wharves of the city are located along the East and West Branches.

b. Westcott Cove. This is a shallow bay covering an area of about 300 acres east of Shippan Point. A channel has been dredged through the cove to a lagoon that was created by the deepening and widening of a small creek that entered the cove from the north.

c. Cove Harbor. This is a shallow indentation of Long Island Sound. It covers an area of about 250 acres east of Westcott Cove. A portion of the north shore of the cove, in Stamford, is being developed by the city for recreational purposes.

d. Holly Pond. This is a shallow, tidal pond of about 200 acres, at the mouth of the Noroton River. Much of the pond area is exposed as mud flats at low tide.

9. TRIBUTARY RIVERS

Two rivers, the Rippowam and the Noroton, flow into tidewater of Long Island Sound at Stamford.

a. Rippowam River. This river rises in the southwestern part of Lewisboro, New York. It flows in a general southerly direction, through Laurel and North Stamford Reservoirs in the northeastern part of the city, then through the main business center, to its

mouth at Stamford Harbor. The lower reach of the river, about 1.25 miles in length, is tidal. This portion is known as the West Branch. The Rippowam River has a drainage area of 40 square miles and a total fall of about 445 feet in its 21-mile length.

b. Noroton River. The Noroton River rises in central New Canaan, Connecticut, and flows in a southerly direction to its mouth at the outlet of Holly Pond on the Stamford-Darien town line. It has a drainage area of 12 square miles and a total fall of about 480 feet in its ten-mile length.

10. TIDES

The mean range of tide at Stamford is 7.2 feet. Spring tides have an average range of 8.5 feet and a maximum range of about 10.3 feet. A high spring tide will reach an elevation of about 9.0 feet above mean low water (5.6 feet above mean sea level). The time interval for a complete tidal cycle averages about 12 hours and 25 minutes. This results in the daily occurrence of two low and two high waters on an average of six out of every seven days. Hurricane tides, which in the recent past have reached a maximum elevation of 11.0 feet, mean sea level, are discussed in paragraphs 36 and 43 of this report.

11. GEOLOGY

Stamford lies on the western edge of the seaboard lowland of the New England physiographic province. The city rests on a physiographic feature known geologically as the Fall Zone Peneplane, an erosional surface which, in effect, is the seaward, beveled edge of the old crystalline rock mass which lies to the north. To the south, the Fall Zone Peneplane dips under Long Island Sound and forms the basement for the Cretaceous rocks and Pleistocene sediments which constitute Long Island.

Stamford Harbor is a coastal indentation produced where a stem of the consequent drainage pattern of the peneplane has produced an estuary. There is little overburden and the rocks, predominantly schistose gneiss of questionable age, slope directly to the Sound and underneath it. The shoreline gives an appearance of youthful submergence, having tombolos and cuspate bars that are largely derived from glacial material. Further data on the geology of the area is contained in Appendix A.

12. AREA MAPS

Stamford and the watersheds of the Rippowam and Noroton Rivers are shown on standard quadrangle sheets of the U. S. Geological Survey at a scale of 1:31,680 and on quadrangles of the U. S. Army Map Service

at a scale of 1:25,000. The Stamford Harbor, Westcott Cove, and Cove Harbor areas are shown on U.S. Coast and Geodetic Survey Charts Nos. 221 and 1213. A map of the area is included as Plate 1 of this report.

ECONOMIC DEVELOPMENT

13. POPULATION

The population of Stamford, according to the state census of 1956, is approximately 84,100. This represents a gain of about 13 percent since 1950 and nearly 40 percent since 1940. This trend is expected to accelerate with the continued development of Fairfield County as a residential suburb of New York City. State interests anticipate that the rate of population increase in Stamford, over the next 20 years, will be greater than that of Connecticut as a whole.

14. INDUSTRY

Manufacturing is the keystone of Stamford's economy. The employed industrial labor force numbers approximately 27,000 of which nearly 55 percent are engaged in manufacturing as compared with a national average of 25 percent. Approximately 230 manufacturing plants are located in the city. Ten of these plants, or five percent of the total, employ 30 percent of the manufacturing workforce. These ten firms produce a variety of durable goods, consisting principally of office machines, electrical equipment, and fabricated metal products, with a combined annual value of $80,000,000. The remaining 220 manufacturing concerns produce a highly diversified line of goods in the electronic, chemical, rubber, paper, engine and machine tool groups. Among the principal items manufactured are x-ray tubes, magnesia compounds, Christmas decorations, sheet metal products, oil burners, and toilet preparations. The industrial output of these firms is valued at $20,000,000 annually. Although employment increases have been noted in all of the city's major industries in recent years, the electrical equipment and chemical groups have shown the largest gains. Laboratories for scientific research in the fields of engineering, electronics, and chemistry, and engaged in limited, specialized production, are important newcomers to the manufacturing segment of Stamford's economy. Other activities include the operation of scrap metal yards; sand, gravel, and concrete plants; and boatyards for the construction, repair, and outfitting of small craft for commercial and recreational purposes.

15. TERMINAL FACILITIES

There are 19 waterfront terminal facilities in the city, all of which are located along the East and West Branches. They have a total available berthage space of about 4,200 feet with depths alongside ranging from about 7 to 22 feet. Ten of the facilities,

with about 2,200 feet of berthage, are located on the West Branch and are used principally for the receipt of petroleum products and coal and coke. The nine facilities on the East Branch are utilized for a number of purposes including the shipment of scrap iron and the receipt of sand and gravel.

Private landings for pleasure craft are scattered along the shores of Stamford Harbor and in the lagoon at the head of Westcott Cove.

16. POWER

The survey area is served by the Hartford Electric Light Company. One plant of this company, a 63,740 kw thermal generating station, is located in the South End of Stamford, on the West Branch. The plant is in an area which was inundated by tidal flooding in 1938 and 1954. Water from the West Branch is utilized by the plant for cooling purposes.

17. AGRICULTURE

Agriculture is quite limited in Stamford and is of no consequence in the areas of the city inundated by hurricane tides.

18. NAVIGATION

The commerce in Stamford Harbor has averaged over 700,000 tons annually during the ten-year period from 1947 to 1956, inclusive. During this period, the annual tonnages have increased from a low of 582,000 in 1947 to a high of 1,030,000 in 1956. This growth is due mainly to an increase in the annual commerce of petroleum products (from 289,000 tons in 1947 to 445,000 in 1956) and in sand and gravel (from 105,000 tons in 1947 to 455,000 in 1956). Approximately 43 percent of the total commerce in 1956 was in petroleum products, 45 percent in sand and gravel, and 11 percent in coal and coke. The remaining tonnage consisted of iron and steel scrap. There is no scheduled passenger service operating out of the harbor.

Annual vessel traffic during the ten-year period from 1947 to 1956 averaged 1600 trips. Traffic ranged from a total of 1396 trips in 1947 to 2030 trips in 1956, excluding towboats. Of the 2030 trips in 1956, six were made by vessels (two tankers and four barges) drawing 15 feet or more, 127 were at drafts of 13 and 14 feet, and the remainder, numbering 897, were made by vessels with drafts of 12 feet or less. In addition to this traffic in 1956, there were 1455 trips by towboats of which 12 drew over 12 feet of water.

It is estimated from a review of the statistics that approximately 18 percent of the total waterborne tonnage in and out of Stamford Harbor in 1956 was to or from wharves on the East Branch. This commerce in the East Branch consisted of receipts of sand and gravel (about 90 percent of the total) and shipments of scrap iron (about 10 percent of the total.) Traffic in the

East Branch in 1956 approximated about 1250 trips. Most of this traffic was comprised of towboats and barges drawing less than 12 feet of water. The largest barge using the East Branch in 1956 had a beam of about 37 feet and drew 10.0 feet of water.

19. TRANSPORTATION

The transportation needs of the area are met by a network of highways and regularly scheduled train, motor, and airline services. U. S. Route 1, the old Boston Post Road, passes through the business center of Stamford in an east-west direction. Closely paralleling Route 1 is the newly-constructed Connecticut Turnpike which also carries traffic moving east or west of the city. This Turnpike connects with the New York Thruway and the New Jersey Turnpike. Also passing through Stamford in an east-west direction, but north of the business center, is the Merritt Parkway, Connecticut Route 15. A number of highways, including State Routes 104 and 137, run northward from the city. Rail transportation, both passenger and freight, is provided by the shoreline route of the New York, New Haven and Hartford Railroad. It connects Stamford with the city of New York and all coastal points in Connecticut as well as the cities of Providence, Rhode Island, and Boston, Massachusetts. Helicopter service between Stamford and Newark, New Jersey, and White Plains, La Guardia and Idlewild Airports, New York, was initiated recently by New York Airways from temporary facilities near the east bank of the East Branch. The selection of this temporary site for the construction of a permanent heliport is under consideration at the present time. The nearest airport for regularly scheduled air service is at Bridgeport, Connecticut, about 25 miles to the east.

20. RECREATION

The waters adjacent to Stamford, together with a chain of fine beaches, provide facilities for boating and bathing which are among the principal recreational activities of the area. The city maintains public beaches and boat anchorages at four waterfront parks: Southfield and Dyke Parks on Stamford Harbor; Cummings Park on Westcott Cove; and Cove Island Park. West Beach, a small beach located on the northwest shore of Westcott Cove, is also maintained by the city. In addition, there are eight municipally-owned parks interspersed throughout the city, most of which provide facilities for outdoor sports. The newly-enlarged sanctuary on the 80-acre estate of the Stamford Museum and Nature Center, with nature trails and picnicking areas, attracts numerous visitors. The city has recently established a program of park and beach improvement to meet the future needs of the community. The considered improvement of East Branch and Horseshoe Beach on Cove Island and the development of a marina in Cove Harbor will enhance the recreational facilities of the city.

21. POLLUTION

The City of Stamford operates a modern sewage treatment plant on the east bank of the East Branch, about 2,000 feet below the head of the Branch. This plant receives sewage from the entire city. The effluent is discharged into the East Branch. During periods of storm and heavy runoff, there is some discharge through relief lines at several scattered locations. A few plants in the south part of the city discharge some industrial wastes directly to the East Branch.

22. FISH AND WILDLIFE

Sports fishing is of little importance in the immediate harbor area. No wildlife habitats of any consequence are located along the waterfront areas of Stamford that are affected by hurricane tides.

CLIMATOLOGY

23. CLIMATE

The climate of the Stamford area is variable and temperate, with occasional extremes in temperature and precipitation. Owing to the moderating influence of nearby Long Island Sound and the Atlantic Ocean, and particularly to the variable movements of high and low pressure systems approaching from the west or southwest, extremes of either hot or cold weather are rarely of long duration. The area is also exposed to occasional storms of tropical origin that travel up the Atlantic seaboard. Although these storms are usually heavily laden with moisture from the ocean, local relief is insufficient to cause orographic rainfall. Coastal storms during the winter frequently bring rain rather than snow which is common in the more northerly areas of New England. Thunder storms, either of local convectional origin or associated with a cold front, may occur at any time of the year. High winds, heavy rainfall, and abnormally high tides occur with unpredictable frequency. Hurricanes can be expected especially during the months of August, September, and October.

24. TEMPERATURE

The average annual temperature in the Stamford area, based on a 61-year record (1893-1953) at Norwalk, eight miles to the east, is approximately 50°F. Average monthly temperatures at Norwalk, during the record period, vary from 27.7°F. in January and February to 72.2°F in July. Recorded extremes have ranged from a minimum of -22°F to a maximum of 104°F. The mean, maximum, and minimum monthly temperatures at the U. S. Weather Bureau cooperative stations at Norwalk are given in Table B-1, Appendix B.

25. PRECIPITATION

The annual precipitation at Stamford is about 46 inches, distributed rather uniformly throughout the year. This is based on a 64-year period of record (1892-1955) at Norwalk. During this period of record, the average monthly rainfall at Norwalk has varied from a maximum of 4.92 inches in August to a minimum of 3.40 inches in June. Extremes in monthly rainfall have ranged from 17.23 inches in October 1955 to 0.07 inches in May 1903. A summary of monthly precipitation data at Norwalk is contained in Table B-2, Appendix B.

HISTORY OF HURRICANES AND OTHER GREAT STORMS

26. HISTORICAL HURRICANES AND GREAT STORMS

Descriptions of hurricanes and other severe storms striking the southern coast of New England can be found in the diaries and records of the first settlers of the Massachusetts Bay Colony. William Bradford, in his chronicle, "Of Plymouth Plantation, 1620-1647," describes a very severe storm that occurred along the coast of Massachusetts on 15 August 1635. Another great hurricane, on 3 August 1638, is described by John Winthrop in his "History of New England from 1630 to 1649". There is no record to indicate that these two storms affected Long Island Sound since there was very little development of the coastal areas of Connecticut until after 1638. However it is reasonable to assume, on the basis of present knowledge of the nature of hurricane surges, that these storms caused inundation of lowlands along the coast of Connecticut.

The history of hurricanes in Connecticut dates back to the storm of 19-20 October 1770 during which two vessels were driven ashore at New London. Early newspapers and diaries contain a number of references to intense storms between 1770 and 1900. The four most notable storms during this period are those of 19 August 1788, 24 September 1815, 4 September 1821, and 24 August 1893. Accounts of tidal flooding along the Connecticut coast in severe storms, other than hurricanes, have been recorded since 1767. Tide gage records at a number of localities along the Sound are available which indicate the height of tidal flooding experienced during the past 20 years.

27. RECENT HURRICANES AND GREAT STORMS

More numerous records are available of hurricanes and other storms that have caused tidal flooding along the Connecticut coast subsequent to 1900, with very good records existing for the years since 1930. Among the more famous storms in the past 28 years, all of which caused tidal flooding of damaging proportions at Stamford, are the following:

HURRICANES	OTHER STORMS
a. 21 September 1938	a. 25 November 1950
b. 14 September 1944	b. 7 November 1953
c. 31 August 1954 ("Carol")	c. 30 November 1944
	d. 14-17 October 1955

The extent of flooding in the storms of 25 November 1950 and 7 November 1953 was equivalent to or higher than that experienced in the 1944 hurricane. During the storm of 14-17 October 1955, high tides ranged from two to four feet above predicted for a 72-hour period and caused damage from tidal flooding. Further data on the history of hurricanes are contained in Appendix C.

28. HURRICANE FREQUENCY

The distribution of recorded hurricane occurrences along the Connecticut coast, by estimated degrees of intensity, is shown in the following table:

TABLE I

RECORDED HURRICANE OCCURRENCES

Connecticut Coast

Category	Years 1770-1800	1801-1900	1901-1956	Total
A. Causing tidal flooding	1	7	6	14
B. Damage from wind and rainfall	2	5	10	17
C. Threat to area; no damage	1	4	22	27
Total	4	16	38	58

Available tide-gage records indicate that there were 21 occasions during the years 1938 through 1956 when the tide reached an elevation of 6.6 feet msl or higher at Stamford. This elevation, about one foot above the level of a high gravitational tide, is just above the stage of flooding where damage begins.

The fact that there is a record of 38 hurricane experiences thus far in the 20th century (1901-1956), as compared with 20 occurrences in the 131-year period between 1770 and 1900, is believed to be due to a lack of records on storm occurrences prior to 1900 rather than a trend toward increased hurricane activity in recent years.

As indicated by recorded facts, the Connecticut coastal area has experienced hurricane tidal flooding upon six occasions since 1900. In addition, storm tides have caused flooding on at least 21 occasions since the first of 1938. Of the six hurricane experiences since 1900, reliable information on high water marks at Stamford is available only for the hurricanes of 1938 and 1954 and for a number of recent storms, other than hurricanes, since 1950. Data is available on tidal-flood levels in the 1944 hurricane and earlier storms at other locations along the Connecticut coast. An elevation-frequency curve(see Plate B-8, Appendix B) has been prepared for Stamford based on (1) known elevations of flooding in two recent hurricanes; (2) estimated flood levels in three other hurricanes, based on descriptive accounts of these storms and/or known high water levels at other Connecticut locations; and (3) the known elevations in a number of other recent storms.

With respect to seasonal variation of hurricane occurrences in southern New England, the period of greatest activity extends from early August to the end of October. However, records indicate occurrences as early as the middle of June and as late as the middle of December.

HURRICANE CHARACTERISTICS

29. GENERAL DESCRIPTION

The term "hurricane" is applied to an intense cyclonic storm originating in tropical or subtropical latitudes in the Atlantic Ocean north of the Equator. Accumulation of heat close to the surface of the water provides energy for water vaporization and the movement of masses of moist tropical air. A hurricane is characterized by low barometric pressures, high winds (75 miles per hour or greater), heavy clouds, torrential rain, tremendous waves, and tidal surges.

30. ORIGINS AND TRACKS

Most of the hurricanes that have affected the eastern coast of North America have formed either near the Cape Verde Islands or in the western Caribbean Sea. Cape Verde hurricanes move

westerly for a number of days with a forward speed of about 10 mph. Occasionally, they proceed straight to the coast of Texas, but generally, after reaching the middle Atlantic Ocean, they recurve northerly and then easterly. Frequently they cross the West Indies, sometimes striking the eastern coast of the United States between Key West, Florida, and Cape Cod, Massachusetts. After recurving, the storms usually increase their forward speed to a rate of 25 to 30 mph and occasionally to a speed of 60 mph. The hurricanes which form in the Caribbean Sea generally move in a northerly direction, across Cuba, then strike either the Gulf or the southeastern shores of the United States. The hurricanes that most severely affect New England usually approach from the south-southwest after recurving east of Florida and skirting the Middle Atlantic states. The paths of a number of selected hurricanes are shown on Plate C-1, Appendix C.

31. WINDS AND BAROMETRIC PRESSURE

The highest winds of a hurricane are those within a circular region extending from the edge of the "eye", or calm center, outward for 10 to 15 miles. The diameter of the eye is usually about 15 miles, although the eye of a mature hurricane may frequently be 20 to 30 miles in diameter. Wind movement is not directly toward the low pressure cyclone center or eye of the hurricane but approaches the center in a counter-clockwise spiral. Consequently, the highest wind velocities occur at points to the right of the hurricane's center where the spiral wind movement and the forward motion of the storm are in the same direction. Since destruction by the wind is greatest in the area on the right side of the hurricane, this area is known as the "dangerous semi-circle." A hurricane following a track over New York City, west of Stamford, would place Stamford in this "dangerous semi-circle."

Atmospheric pressure falls rapidly as the center of the hurricane approaches and as the velocity of the wind increases. Minimum barometric readings do not always occur in the center of the eye. In some instances, the minimum is reached at the beginning of the calm period, while in others, the minimum is reached at the end of the calm period. Usually the barometric low is about two inches below the normal sea level pressure of 30 inches. However, in several hurricanes, pressures as low as three inches below normal have been recorded. The lowest barometric pressure of record in the United States, 26.35 inches, was recorded at the northern end of Long Key, Florida, on 2 September 1935.

32. RAINFALL

Another characteristic of a hurricane is the heavy rainfall that usually accompanies the storm. The rainfall at the edge of the disturbance is light, normally in the form of showers. As the

center approaches, the showers increase in frequency and intensity, becoming heavy to excessive near the eye. The heaviest rain usually falls ahead of the eye, driving torrentially from spiral bands of clouds that sometimes produce nearly two inches of rain per hour. For a 24-hour period, amounts exceeding 20 inches are not uncommon. In New England, the hurricane of September 1938 caused rainfall of 6 to 8 inches, in a one-day period, at a number of locations; in the 1954 hurricane, one-day rainfalls of 4 to 5 inches were recorded. The record rainfall in New England, associated with a hurricane, occurred during Hurricane "Diane" (August 1955) when a rainfall of 15.7 inches in 24 hours (total storm rainfall of 19.8 inches in 48 hours) was experienced at Westfield, Massachusetts, 85 miles northeast of Stamford. This hurricane, however, had lost its typical characteristics - high winds and surge - by the time it reached and stalled over New England.

33. WAVES

Much of the hurricane damage is caused by waves generated by hurricane winds. Vessels at sea suffer greatly in the northeast quadrant of the hurricane and in the turbulent seas of the storm center where waves 45 feet or more in height have been reported. These mountainous waves appear in wild, pyramidal masses and the magnitude of their destructive power is revealed only in the appalling record of lives lost and ships sunk at sea or wrecked on shoals and shores. Such ocean waves will traverse tremendous distances while diminishing in size and strength, reaching distant shores one or two days in advance of the hurricane and causing damage even before the onset and release of the fury contained in the storm proper.

In the deep water of the open ocean the height, period, and velocity of many of the waves produced are a function of the wind velocity. The ultimate size of the waves depends upon the force and duration of the wind and the fetch or distance the wave travels. As ocean waves come into shoal waters, their forward movement is slowed by friction on the bottom, and they rise to a new height before they are dissipated in shoal waters or break on the shore. Driven by hurricane winds, the breaking waves will run up on a shelving beach or overtop vertical structures well above the wave heights, so that reports of wave and flood damage from 5 to 25 feet above stillwater level are not uncommon. Hurricane waves do great damage to shorefront land and buildings and to vessels and small craft.

No data is available on experienced wave heights at Stamford during past hurricanes. Computations based on a wind velocity of 35 miles per hour, from the west southwest, at the time of peak flooding, in a design hurricane, (see paragraphs 39 to 42) indicate

that wave heights of 6.0 feet would be experienced at exposed locations near the entrance of Stamford Harbor and along the shore of Westcott Cove. This wave height, due to refraction, would be reduced to 3.6 feet in the protected areas of the harbor inside the breakwater. This wind velocity and direction are not critical insofar as wave heights are concerned. The most critical winds would occur in the Stamford area if the hurricane center were located west of Stamford, near New York City. Under this condition the tidal surge at Stamford would be negligible. A wind speed of 95 mph, from the south, would create waves of 10-foot height at the entrance to the harbor, coincident with a spring tide level of 5.6 feet msl. These waves would be reduced to 2 to 4 feet along the shores of the East and West Branches.

34. TIDAL SURGES

Flooding results from the movement of the storm surge, or rise in water level, onto a shoaling coast or into a bay or inlet. The surge is caused by a combination of hurricane winds and low barometric pressure in a storm having a track and speed of forward movement synchronized with the normal pattern of tidal movement and oscillations of the sea in the open ocean.

Generally the rise of the sea is gradual as the center of the storm approaches but sometimes it comes with great swiftness. The history of terrible storms, revealing many instances of cities and towns flooded, with thousands of lives lost, evidence that such rises are not always gradual.

Usually the level of the storm surge is increased by a rising ocean bed and favorable shore contours, factors which similarly affect the astronomical tide in shore locations. The ordinary rise of the tide amounts to only one or two feet in the open ocean while its range is often ten to twelve feet at coastal points. In certain bays and channels the rise is 25 to 50 feet above low water. The times of ebb and flow of such tides are of course well known, but the storm surge comes so rarely to any one community that it is seldom anticipated in its fully developed form. A well defined storm surge is not developed unless the slope of the ocean bed and the contour of the coastline are favorable to its rise, in combination with the proper direction of the storm track and speed of movement. Tidal flooding along the Connecticut coast occurs as the storm surge accompanying northward-moving hurricanes, passing east of Stamford, moves up Long Island Sound from its eastern end. The time lag for the surge to reach the western end of the Sound is approximately three hours.

35. WIND FIELD AND BAROMETRIC PRESSURE

In New England, the maximum recorded wind velocity in a past hurricane is a gust of 186 mph at the Blue Hill Observatory, Milton, Massachusetts, in September 1938. The sustained 5-minute velocity at this location, about 150 miles northeast of Stamford, during this same hurricane, was 121 mph. At New York City, about 30 miles to the southwest of Stamford, the maximum gust and 5-minute velocity in this hurricane were 80 and 70 mph, respectively. At New Haven, Connecticut, 35 miles east of Stamford, and at Hartford, Connecticut, 65 miles northeast, sustained winds of 38 and 46 mph were recorded with gusts of 46 and 59 mph.

During the hurricane of September 1944, the maximum gust in New England was an estimated 104 mph at Hartford, Connecticut. A wind of 99 mph, for one minute, and a 5-minute velocity of 81 mph were recorded at New York City during this storm. At New Haven, Connecticut, the recorded maximum gust was 65 mph and the sustained 5-minute wind was 33 mph.

Peak gusts measured during Hurricane "Carol", in August 1954, are 142 mph at Mount Washington, New Hampshire, 250 miles northeast of Stamford, and 130 mph at Block Island, Rhode Island, 100 miles to the east. Gusts of 65 and 64 mph, respectively, were experienced at New Haven and Hartford. A maximum velocity of 52 mph was recorded at Stamford during this hurricane in 1954, the first year of record at this locality.

Low atmospheric pressures are characteristics of the "eye" of a hurricane. The lowest barometric pressure ever recorded in New England is 28.04 inches at Hartford, Connecticut during the 1938 hurricane. At New Haven, a low of 28.11 inches was recorded during the same hurricane. The New England low for the September 1944 hurricane is 28.31 inches at Point Judith, Rhode Island, about 100 miles east of Stamford. In Hurricane "Carol" (1954) the pressure fell to 28.20 inches at Storrs, Connecticut, 85 miles northeast of Stamford. A low of 28.77 inches was recorded at New Haven. No records of barometric pressures have been obtained at Stamford.

Further data on wind velocities and barometric pressures in past hurricanes are included in Appendix B.

36. ASTRONOMICAL TIDE AND TIDAL FLOODING

An important factor in determining the height of flooding from a hurricane surge is the stage of the normal tide at the time the surge arrives at the coast. The surge in the September 1938 hurricane

added 8.0 feet to the astronomical tide at Stamford and caused flooding to an elevation of 11.0 feet msl (approximately 7.2 feet mhw). The hurricane of 31 August 1954 (Hurricane "Carol"), with a 5.9-foot surge, caused flooding to an elevation of 10.3 feet msl. Hurricane highwater elevations, predicted coincident astronomical tides, and the storm surges in the three major hurricanes and two other severe storms that have struck the city of Stamford in recent times are tabulated in Table 2 below.

TABLE 2

TIDAL - FLOOD DATA

Stamford, Connecticut

Date	Time of Peak (EST)	Hurricane High-Water Elevation (feet msl)	Coincident Gravitational Tide (feet msl)	Storm Surge (feet)
Hurricanes				
21 Sep 1938	7:45 PM	11.0	3.0	8.0
14 Sep 1944	11:30 PM	9.2	2.0	7.2
31 Aug 1954	12:55 PM	10.3	4.4	5.9
Other Storms				
25 Nov 1950	12:00 N	9.5	-	-
7 Nov 1953	10:45 AM	9.2	-	-

The duration of tidal flooding, above the elevation of mean high water, was about five hours in the 1938 and 1954 hurricanes and five and one-half hours in the 1944 hurricane. Further data on tidal high water elevations may be found in Appendix B.

Peak flooding in the 1938 hurricane occurred about one hour and forty minutes before a predicted astronomical high tide of 4.8 feet msl; the 1944 hurricane occurred about two hours after a predicted high tide of 4.0 feet msl; and the 1954 hurricane occurred practically simultaneously with the peak of a predicted high tide of 4.4 feet msl. The greatest surge was 8.0 feet, in 1938. Although the surge in the 1954 hurricane was 2.1 feet less than that of 1938, the elevation of tidal-flooding in 1954 was only 0.7 foot below the 1938 level due to the stage of tide at the time of peak flooding. Similarly, although the 1944 surge exceeded that of 1954 by 1.3 feet, the elevation of flooding in 1944 was 1.1 feet less than the experienced level in 1954. Had the surge in the 1954 hurricane been equal in magnitude to that of the 1938 storm, flooding in 1954 would have reached an elevation of 12.4 feet msl, or 2.1 feet higher than was

actually experienced. If these three storms had struck Stamford at a time coincident with a maximum spring tide of 5.6 feet msl, flooding would have been experienced to an elevation of 13.6 feet msl in 1938, 12.8 feet in 1944, and 11.5 feet in 1954; or 2.6, 1.8, and 0.5 feet higher than the flooding sustained in 1938.

In determining future tidal-flood levels, one factor to be considered is the rise in mean sea level that is taking place along the New England coast. Continuing investigations being made by the U. S. Coast and Geodetic Survey in regard to changes in sea level indicate that the elevation of mean sea level has risen at a rate of approximately 0.02 foot per year since 1930. (See report by the Council on Wave Research in Proceedings of the First and Second Conferences on Coastal Engineering, 1952.) If this trend continues and storms of the magnitude of the 1938 and 1954 hurricanes were to occur at the end of the next 50 years, flood levels would be approximately one foot higher than were actually experienced in these storms. The effect of rising sea level is to increase the severity of future hurricane tidal flooding.

37. STORM TRACKS

Each of the three recent great hurricanes, namely those of 1938, 1944, and 1954, followed paths located to the east of Stamford: the 1938 hurricane path being about 25 miles to the east; the 1954 hurricane, 75 miles; and the 1944 hurricane, 85 miles. These paths were not critical to Stamford insofar as wind intensities were concerned but they did place the eastern entrance of Long Island Sound in a sector of each hurricane where high storm surges are experienced. These surges then travelled up the Sound to produce tidal flooding at Stamford. A hurricane surge entering New York Harbor, by reason of following a path west of Stamford, would undergo a considerable reduction in magnitude before entering the western end of Long Island Sound by way of the East River.

38. SELECTION OF DESIGN HURRICANE

In the design of protective works for Stamford, structures must be sufficiently high and strong to withstand the most severe combination of storm tide and wave action that can reasonably be expected. A design hurricane for use in determining the required height of protective structures has been established through the cooperation of the U. S. Weather Bureau and the Beach Erosion Board, assisted by personnel of the Agricultural and Mechanical College of Texas.

The basis for the design storm is a transposition of the September 1944 hurricane. This hurricane, off Cape Hatteras, had the greatest amount of energy of any known hurricane, including that of September 1938. I. R. Tannehill, in his book, "Hurricanes: Their Nature and History," 1956, states in reference to the September 1944 hurricane, "....there is no definite proof of a more violent hurricane in the records." However, the 1944 hurricane when it struck New England was not nearly so serious along the Rhode Island and Connecticut coasts as either the September 1938 or August 1954 hurricanes because its energy had been partly dissipated over the land north of Cape Hatteras. Moreover, it struck at a time of lower tide.

In deriving the design hurricane, the 1944 storm was transposed so that it would be entirely over water from the Cape Hatteras area to the New England coast. This change in the track of the storm results in less rise in barometric pressure at the center of the storm as it moves northward than was actually experienced in 1944. The transposed hurricane is assumed to advance in a due northerly direction with a forward speed of 40 knots (about 46 mph) in one case, 30 knots (about 34 mph) in a second case, and to pass over New England at a point 49 nautical miles (56 statute miles) west of Montauk Point, Long Island, near the eastern entrance to Long Island Sound. This change in the track of the storm produces the highest surges along the Connecticut coastline, on the north shore of Long Island Sound.

39. DESIGN FLOOD LEVELS

The 1938 hurricane storm-tide potential at the eastern entrance to Long Island Sound has been calculated at 9.5 feet. The surge at this same location, in the event of a design hurricane, has been determined to equal 13.4 feet or 1.4 times the 1938 surge. The computation of these storm-tide potentials has been made by members of the staff of the Department of Oceanography of Texas A & M College in connection with research work conducted by them for the Beach Erosion Board.

The storm-tide potential for Stamford Harbor, under design hurricane conditions, is estimated at 10.4 feet. This design storm tide or surge of 10.4 feet is nearly 30 percent greater than the 1938 surge which is the greatest experienced during the past 50- to 60-year period of reliable records. The addition of a 10.4-foot surge on top of a spring tide gives a design tidal-flood level of 16.0 feet msl or 5.0 feet higher than the level of flooding experienced in 1938. The derivation of the design storm-tide potential is contained in Appendix B.

40. DESIGN WAVES AND RUNUP

Significant wave heights under conditions of a design hurricane, with a wind velocity of 35 mph from the west southwest at the time of peak flooding, and a surge of 10.4 feet on top of a spring tide of 5.6 feet msl, are estimated as follows:

a. Entrance to Stamford Harbor (outside breakwaters): 6 feet

b. Mouth of East Branch: 4 feet

c. West Branch: 2 feet

d. Westcott Cove: 2 feet

e. Cummings Park (near lagoon): 2 feet

Significant wave heights are equivalent to the average height of the highest one-third of all the waves in a wave train. These heights are exceeded by about 13 percent of all waves in the train, the maximum wave heights being about 60 percent higher and occurring about one percent of the time.

The wave runup on the seaward side of protective works in the West Branch varies from about one foot for dikes to four feet for vertical walls; for the East Branch protection, about three to four feet for dikes and six feet at the navigation gate; and, in the Westcott Cove-Cummings Park area, about one foot for dikes. The runup values for the dikes and the barrier are based on rubble slopes of rough angular stone (dike slopes of 1 on 1.5, barrier slope of 1 on 2.5). The subject of hurricane waves, including runup and overtopping, is considered in further detail in Appendix B.

41. DESIGN RAINFALL

Design rainfall is based on a total recorded rainfall of 13.29 inches in 73 hours at Stamford during the storm of 14-17 October 1955. Since the readings at Stamford were made only at 24-hour intervals, data on rainfall intensities during this storm were estimated from the record of recording gages at two nearby locations, Candlewood Lake, Connecticut, and Brentwood, Long Island. The maximum 12-hour rainfall in this storm was 7.86 inches and the maximum one-hour intensity was 2.07 inches. Mass curves of rainfall at Candlewood Lake and Brentwood are shown on Plate B-2, Appendix B. A developed mass curve for Stamford is also shown on this plate.

42. DESIGN RUNOFF

The runoff that will occur in the south portion of the city from the design rainfall of 7.86 inches in 12 hours amounts to a total of approximately 6.7 inches. With this runoff, a peak discharge of 1,275 cfs is obtained for the 1211-acre drainage area of the East Branch. This area includes the 54-acre water surface of the Branch itself. For the area of 172 acres draining to a depressed area in the South End, with a minimum ground elevation of about 2.5 feet msl, in the drainage area of the West Branch, the peak discharge is 264 cfs. To reduce the amount of runoff ponding in this area during times of heavy rainfall, the city has a small pumping station, rated at 10,000 gpm, located in the depressed area at Pacific and Crosby Streets, and a gravity drainage system for about 50 acres. Further data on design runoff are contained in Appendix B.

EXTENT AND CHARACTER OF FLOODED AREA

43. The hurricanes of 21 September 1938 and 31 August 1954 caused tidal flooding to elevations of 11.0 and 10.3 feet msl, respectively, and at these elevations inundated about 930 acres in Stamford. The major portion of the flood damages was sustained in the South End, in an area of approximately 200 acres between the East and West Branches, at the head of Stamford Harbor. The flooded area in the South End is thickly settled by residential and industrial properties, including some of the principal manufacturing plants of the city, and a generating station of the Hartford Electric Light Company. All of the principal commercial wharves and their adjoining facilities are located in the flooded area, along both banks of the East and West Branches. The remainder of the flooded area, adjoining the shores of Stamford Harbor, Westcott Cove, Cove Harbor, Holly Pond and the Noroton River is largely urban.

Although the tidal-flood damages to commercial, public, and residential properties were substantial in past hurricanes and storms of recent date, information obtained by damage-survey parties indicates that the greater part of the damage in Stamford is experienced by manufacturing concerns. See Table 3 and paragraph 45. Nearly 75 percent of the 1954 flood damages occurred in the South End, between the two Branches, and in a small area north of the railroad above the head of the East Branch. Industry in the South End employ about 5,000 people, or approximately one-third of the total manufacturing labor force of the city. The areas of the city flooded in 1938 and 1954 are shown on Plate D-1, Appendix D.

HURRICANE TIDAL-FLOOD DAMAGES

44. FLOOD-DAMAGE SURVEY

Information on tidal-flood damages sustained as a result of the 1954 hurricane was obtained by damage survey parties in the winter of 1956-1957. Data were collected on the extent and nature of the areas flooded, the depth of flooding, and the amount of damages that were experienced during Hurricane "Carol," 31 August 1954. Losses were estimated for various stages of flooding above and below the 1954 flood level to develop stage-loss relationships. Much of the information was obtained through personal interviews, although sampling methods were used whenever similar types of property, subject to approximately the same depth of flooding, were encountered.

45. EXPERIENCED TIDAL-FLOOD DAMAGES

Hurricane "Carol" caused damages from tidal flooding in Stamford that amounted to $3,430,000. The major portion of the total loss, over 60 percent of the total, was sustained by industrial properties. The distribution of the total loss by type of damage is shown in the following table. The geographical distribution is shown on Plate D-1, Appendix D.

TABLE 3

EXPERIENCED TIDAL-FLOOD DAMAGES

Hurricane "Carol," 31 August 1954

Stamford, Connecticut

Type	Damages
Industrial	$2,095,000
Urban (1)	1,280,000
Rural	25,000
Highway	30,000
Total	$3,430,000

(1) Includes residential, commercial, and public.

In addition to extensive urban and industrial losses there were some damages sustained by boats and automobiles in the flooded area which were not included or were included only in part since information on such types of loss was meagre or unavailable. The

indications are that the losses of this nature were not substantial in Stamford. Other unevaluated losses include intangible damages such as loss of life, impairment of health and welfare, and menace to national security. More detailed data on experienced tidal-flood losses are contained in Appendix D.

46. RECURRING TIDAL-FLOOD DAMAGES

Using stage-damage relationships obtained from the field investigation of damages, estimates have been made of recurring damages, at 1957 price levels, that would be experienced in future hurricanes causing flooding at various stages at, above, and below the 1954 flood level. These losses are summarized in Table 4, below.

TABLE 4

RECURRING TIDAL-FLOOD DAMAGES
(1957 Price Level)

Stamford, Connecticut

Equivalent Hurricane	Flood Stage (feet msl)	Damages
31 Aug 1954	10.3	$3,050,000
21 Sept 1938	11.0	5,790,000
14 Sept 1944	9.2	620,000
Other Storms		
25 Nov 1950	9.5	960,000
7 Nov 1953	9.2	620,000

Further data on the determination of recurring losses are included in Appendix D.

47. AVERAGE ANNUAL TIDAL-FLOOD LOSSES

Average annual tidal-flood losses in Stamford, as determined from damage-frequency relationships, are estimated at $498,000, at 1957 price levels. The stage-frequency curve used in determining losses was based on known tidal-flood elevations at Stamford in the 1938 and 1954 hurricanes and a number of storms, other than hurricanes, since 1938, and estimated elevations based on newspaper accounts and known elevations of flooding at other locations along the Connecticut coast. This curve was correlated with stage-damage information to derive a curve of damage frequency. The area under the damage-frequency curve represents the average annual losses.

48. SCARE COSTS

In addition to sustaining actual tidal-flood damages, a number of concerns in the flooded area of Stamford incur significant costs, upon the receipt of a hurricane warning, for instituting temporary preventive measures to minimize the damages that they would sustain if the threatening hurricane should strike. These are costs that are incurred even though the anticipated hurricane causes no tidal flooding. Included among the temporary measures are provisions for sandbagging and plans for the temporary removal of goods and equipment from space likely to be flooded. It is estimated that "scare costs" to local, commercial, and industrial interests in Stamford amount to approximately $44,000 at 1957 prices, for each hurricane scare. Based on a frequency of four warnings every ten years, a frequency consistent with records of the past 50 years, average annual scare costs in Stamford amount to $17,000.

EXISTING CORPS OF ENGINEERS' PROJECTS

49. HURRICANE PROTECTION PROJECT

There is no existing Corps of Engineers' hurricane protection project for the prevention of hurricane tidal-flood damages in the city of Stamford.

50. NAVIGATION PROJECTS

a. Stamford Harbor. Federal improvement of Stamford Harbor in the interests of navigation dates back to 1883. The existing navigation project provides for the following:

(1) An entrance channel 200 feet wide, 18 feet deep at mean low water, from deep water in Long Island Sound to the upper end of an 18-foot anchorage, a distance of about 0.5 mile, and thence 15 feet deep to the junction of the East and West Branches, an additional distance of 0.5 mile.

(2) A channel 12-feet deep in the East Branch, 100 feet wide, with increased width at the turns, to a point 1,100 feet below the head of navigation, thence 85 to 125 feet wide to the head of navigation, a total distance of about 1.5 miles.

(3) A channel 15 feet deep in the West Branch, 125 feet wide and about three-fourths of a mile long, and a basin of the same depth at the head of the Branch.

(4) Two anchorages, one of 20 acres, 18 feet deep, on the west side of the 18-foot entrance channel, and one of 4.2 acres 8 feet deep, on the east side of the East Branch, about 4,500 feet above the junction of the East and West Branches.

(5) Two detached breakwaters at the entrance to the outer harbor, one, 1200 feet long, on the easterly side of the channel, and one, 2,900 feet long, on the westerly side.

b. Westcott Cove. The existing project provides for a channel 100 feet wide and 8 feet deep, from deep water in Long Island Sound, through Westcott Cove, to the south limit of the lagoon at Cummings Park.

The existing project for Stamford Harbor is about 88 percent completed. To complete the project there remains the dredging of a slight widening in the East Branch channel opposite Ludlow Street and dredging of the 8-foot anchorage adjacent to the East Branch channel. The existing project for Westcott Cove was completed in 1957. The mean low water controlling depths in the 18-foot entrance channel and anchorage were 17 feet and 16 feet, respectively, in 1954; in the 15-foot entrance and West Branch channels, 11 feet (1957) with a 15-foot depth available in the center of the channels for one-half their width; and in the 15-foot basin at the head of the West Branch, 10 to 12 feet (1957). The controlling depth in the 12-foot East Branch channel, in 1956, was 8 feet except for an area along the westerly edge, not yet dredged, where there is a depth of 3.5 feet. The present controlling depths appear to be adequate to meet the needs of existing commerce. The 7.2-foot range of tide permits use of the waterways by vessels with drafts in excess of the present controlling depths.

51. BEACH EROSION CONTROL PROJECTS

The recommended beach erosion control work at Stamford provides for widening to a 125-foot width, by direct placement of sand, 1,200 feet of the east shore at Cove Island and 1,000 feet of the public beach at Cummings Park, on the north shore of Westcott Cove. It also provides for (1) the construction of an impermeable jetty, 400 feet long, at the east limit of the shore improvement work at Cove Island, (2) lengthening to 400 feet the existing groin at the beach at Cummings Park, and (3) raising the inshore end of the existing jetty at the east entrance to the Cummings Park lagoon to an elevation of 13 feet, mean low water. Local interests have initiated no work to date on the recommended improvement. The State of Connecticut has scheduled construction of the recommended project at Cove Island during the current biennium using available state funds.

HURRICANE PROTECTION IMPROVEMENTS BY OTHERS

52. FEDERAL AND STATE IMPROVEMENTS

No improvements in the interest of minimizing hurricane tidal-flood damages in Stamford have been undertaken by any other Federal agencies or by the State of Connecticut.

53. LOCAL IMPROVEMENTS

The city of Stamford has constructed a low dike, with a minimum top elevation of about nine feet msl, along the west side of Dyke Lane, near its southerly end, to prevent the overflow of spring tides into a low area of the South End at Pacific and Crosby Streets. Two portable 7,500 gpm pumps are utilized at times, near the foot of Dyke Lane, to prevent ponding.

A number of industrial and commercial establishments have installed permanent or semi-permanent measures to reduce the damages that they would individually sustain in future hurricanes. These measures include the following:

a. The provision of means to afford permanent or temporary closure of doorways and other openings.

b. The installation of valves or gates to prevent backup in pipelines.

c. The construction of flood walls.

d. The installation of pumps to control seepage and interior drainage.

e. The reinforcing of floors and walls.

f. Changes in the utilization of space susceptible to flooding.

g. The provision of racks and other means to permit the storage of material and the installation of motors and equipment above the experienced level of flooding.

h. The adoption of flood mobilization plans providing for evacuation of personnel and the raising or removal of goods and equipment.

IMPROVEMENTS DESIRED

54. PROPOSALS BY LOCAL INTERESTS

Local interests evidenced a desire for protection against hurricane tidal flooding even before the passage of Public Law 71 which authorized this survey. In October 1954 they engaged a private engineering firm to make a preliminary investigation and prepare a report on the planning of flood protection works to prevent inundation of low-lying areas of the city from abnormally high tides. This

report, which was submitted to the city in March 1955, recommended a plan of protection providing for a system of dikes and walls along a portion of the east bank of the West Branch, along both banks of the East Branch, and in the Westcott Cove-Cummings Park area. Protection was designed with a top elevation of 16 to 17 feet mlw (12.6 to 13.6 feet msl). Provisions were included for the installation of a 75,000 gpm pumping plant on Dyke Lane, in the South End. This plant would also handle storm runoff during normal high tides and thereby improve existing interior drainage conditions.

55. MEETING WITH LOCAL INTERESTS

During the course of the survey, a number of meetings have been held with representatives of both State and local governments as well as with representatives of local commercial and industrial interests. The purposes of the meetings have been to ascertain the desires of local interests, to acquaint them with the progress being made on the survey, and to afford an opportunity for the exchange of ideas and comments on the survey and the various plans of protection being considered. At these meetings, local interests reiterated their need for protection from hurricane-induced tidal flooding. They expressed general approval and preference for a plan providing protection by means of a barrier across the East Branch, with a gated opening for navigation, and dikes and walls along the east bank of the West Branch and in the Westcott Cove-Cummings Park area of the city. This is Plan "E" as discussed in paragraphs 63 to 75.

56. PUBLIC HEARING

A public hearing was held in Stamford, Connecticut, on 12 February 1958, for the purpose of acquainting local interests with the results of the survey and determining their views and opinions. The meeting was attended by about 250 persons including representatives of members of Congress, State and local officials, representatives of local industrial and commercial interests, and home owners. At this meeting, local interests restated their need for protection and expressed their approval of Plan "E". No general opposition to the alignment of Plan "E" protective works was presented. Representatives of two commercial interests engaged in boating activities expressed the desire that consideration be given to modifying the type of protective structure considered at the east end of the East Branch barrier in order to reduce the amount of land taking. One home owner requested that a change in alignment be made to avoid the possibility of having to acquire one summer and one year-round

home. Disagreement with the selected widths of the navigation opening in the East Branch barrier and temporary bypass channel to be provided for use during the construction period was expressed in a communication received from a representative of towboat interests. This objection, to any widths less than the present channel width of 100 feet, was read into the minutes of the hearing. Subsequently, a letter was received setting forth the objections in more detail and modifying the original protest to the extent of (1) reducing the desired width of opening to 90 feet, instead of 100 feet, and (2) withdrawing the objection to a width of 75 feet in the temporary bypass channel.

TIDAL-FLOOD PROBLEM AND SOLUTIONS CONSIDERED

57. TIDAL-FLOOD DAMAGES

Hurricane damages result chiefly from (1) salt-water flooding by the hurricane surge, (2) action of storm-driven waves, (3) fresh-water flooding resulting from torrential rains, and (4) effect of high-velocity winds. This report is limited to the damages arising from salt-water tidal flooding and wave action. Fresh-water runoff and flood damages are considered only to the extent that they affect areas in Stamford that are subject to tidal flooding. The inundations of low coastal areas by hurricane tides and the fresh-water flooding in river valleys account for the major portion of damages in hurricanes. Hurricane "Carol" (1954) caused severe flooding of shorefront areas along the Connecticut coast, including Stamford. In the following year, the rainfall associated with Hurricane "Diane" inflicted heavy flood damages along the river valleys in Connecticut, Massachusetts, and Rhode Island. However, by the time this storm reached New England it had slowed down considerably and lost the general characteristics of a hurricane.

Damages are also incurred along the Connecticut shore by severe storms, other than hurricanes, that are accompanied by strong easterly winds. Since the Connecticut shore is practically landlocked, these storms cause abnormally high tides. Storms of this nature on 7 November 1953 and 25 November 1950 caused serious tidal-flood damages in the city of Stamford. During the storm of 14-16 October 1955, high tides at Stamford were sustained at elevations ranging from two to four feet above predicted for a period of three days.

Damages caused by hurricanes and other great storms consist of the loss of life and property, hazards to health, disruption of normal economic activities, and costs of evacuation and reoccupation. Some types of damage cannot be prevented, although they may be relieved be careful planning. Protection against hurricane winds, for example, can be realized to some extent by the adoption of higher building code standards. Some New England localities have adopted such measures. Damages resulting from tidal flooding of coastal areas or fresh-water flooding of river valleys can be significantly reduced in some cases by protective structures.

58. HURRICANE FLOOD PROBLEM

The problem, in general, is one of providing protection to the industrial, commercial, and urban areas of Stamford which sustained damages of $3,430,000 from tidal flooding in Hurricane "Carol" (31 August 1954). The greater part of this damage, nearly 75 percent of the total, was experienced in the South End, between the East and West Branches. The South End area, which covers about one-quarter of the total flooded area of the city, is densely occupied by industrial plants, commercial establishments, and dwellings. Practically all of the principal commercial wharf facilities are located along the banks of the two Branches at the head of the harbor. The problem resolves itself mainly into one of determining the possibilities of providing economically justifiable protection for the thickly settled area of the South End with a minimum amount of disruption to existing facilities.

59. DEGREE OF PROTECTION REQUIRED

The degree of required protection is indicated by the fact that the city experienced tidal flooding to an elevation 7.2 feet above mean high water (11.0 feet msl) in the hurricane of 21 September 1938, and to an elevation 6.5 feet above mean high water (10.3 feet msl) in Hurricane "Carol" on 31 August 1954. Properties in the flooded area in 1954 were inundated to depths ranging up to four feet. In the event of a design hurricane occurring coincident with the peak of a spring tide, the waters of Stamford Harbor and Westcott Cove would rise to an estimated elevation of 16.0 feet msl. This would cause flooding to depths of nearly ten feet over some properties. In addition to providing protection to an elevation of 16 feet msl, an increased height of protection must be provided in some locations in order to minimize the effects of overtopping by waves.

60. PROTECTIVE MEASURES CONSIDERED

Protective measures fall into the following categories: (a) hurricane warning and emergency flood mobilization measures, including plans for evacuation; (b) revised zoning regulations and building codes; and (c) protective structures. They are described below.

a. Hurricane warning and emergency flood mobilization measures. A hurricane warning system, combined with emergency mobilization and plans for evacuation would materially aid in preventing loss of life and property. However, such a system would not alleviate the problem of physical inundation of land area. Considerable time is required for emergency precautionary measures, such as boarding

up and sandbagging windows, evacuating low-lying areas, removing goods and equipment to higher levels, pulling small craft ashore, and driving vehicles to high ground. A warning system, no matter how extensive and elaborate, may not always provide sufficient time for taking adequate precautions. The hurricane of 1938, for example, which was reported stalled at one time off Cape Hatteras, swept north to the New England coast, almost unannounced, only eight hours later.

Hurricane alerts and "near misses", resulting only in "scares", interfere with the normal activities of affected residents and, in many cases, cause economic loss. It is estimated that a single hurricane "scare" incurs costs of $44,000 to industries in Stamford. The hurricane warning services now provided by the U. S. Weather Bureau are necessary, however, to supplement any plan of protection for the city.

b. Revision of zoning regulations and building codes. The consideration of warnings and emergency measures leads to thought being given to the relocation of goods and equipment to higher floor levels, relocation out of the flood area entirely, or of more substantial construction to resist the destructive forces of high water and waves. State and local governments, in some instances, have proposed adoption of zoning restrictions to prevent new construction in critical flood areas and revisions of building codes to require sturdier construction in areas where buildings have been demolished by storm tides. Such measures, where proposed for existing concentrations of homes, commercial establishments, and industries, tend to meet with strong opposition because of the high investment in property and the prospective loss to property owners and municipalities. The responsibility for enacting legislation on zoning and building regulations lies with the state and municipalities concerned.

c. Protective structures. Although hurricane warnings, mobilization measures, and revised zoning regulations and building codes will abate the extent of flood damages, they will not eliminate the inherent danger from tidal flooding. The most positive means of protection consists of structures which will physically reduce or prevent the inundation of properties by tidal-flood waters that enter Stamford Harbor at the time of a hurricane. Considered structures include barriers, with gated or ungated openings, which will completely or partially close off the waterway to the entry of hurricane tides; dikes or walls on shore, which will hold back the high water; or a combination of barriers, dikes, and walls. The construction of breakwaters or the enlargement of existing breakwaters

would effect a reduction in the height of hurricane waves but would be ineffective in preventing the flooding of shore properties. Damage solely by hurricane waves at Stamford has been negligible in the past.

61. PLANS CONSIDERED

Consideration has been given to nine different plans of protection and to several variations entailing minor modifications in either the alignment or type of structure included in the plans. All of the nine plans were predicated mainly on the basis of providing protection to the South End where the greater part of the tidal-flood damages in the city were experienced during the hurricanes of 1938 and 1954. In general, the plans include protection against flooding from the West Branch, the East Branch, and Westcott Cove.

a. West Branch Protection. With one exception, all of the considered plans include dike and wall protection along the east bank of the West Branch. The greater part of the protection follows the property lines and shore frontage of the Hartford Electric Light Co.

b. East Branch Protection. Eight plans provide protection against flooding from the East Branch. One affords protection by means of dikes and walls along the entire west bank of the Branch to high ground near the railroad, at the upper end of the Branch. Under this plan no protective works are provided on the east shore of the Branch or in the Westcott Cove area. Two of the plans provide protection by means of dikes and walls along both banks in conjunction with protection in the Westcott Cove area. Each of the five remaining plans calls for dikes together with a barrier across the Branch. Crossings of the Branch were considered at the five following locations:

(1) A point about 1,000 feet below the head of navigation at Jefferson Street. This plan would close the upper end of the Branch to navigation.

(2) At Ludlow Street, about 2,500 feet below the head of navigation. The plans for crossing at this location include a barrier with no opening and one with a gated opening to permit navigation to upstream wharves.

(3) At the upper end of Woodland Cemetery, about 3,000 feet below the head of the Branch. This plan calls for a gated opening in the barrier.

(4) At the lower end of Woodland Cemetery, about 1,000 feet above the mouth of the Branch, with a gated opening for navigation. This is the barrier included in Plan "E" that is described in subsequent paragraphs.

(5) At the mouth of the Branch, in the vicinity of Ware Island. The considered barrier at this location includes a gated opening as in Plan "E".

c. Westcott Cove Protection. All but three of the nine plans include protection in the Westcott Cove area to prevent overflow from the cove to the East Branch. Two general alignments were studied. One starts midway along the west shore of the cove and follows the shoreline to its eastern extremity. This necessitates a barrier crossing, with gated opening, at the entrance to the lagoon at the head of the cove. The second also starts about midway along the west shore but follows a line inland of the lagoon and across Cummings Park.

d. Outer Barrier. The ninth plan affords complete protection by means of a barrier across the entrance to Stamford Harbor, along the alignment of existing breakwaters, supplemented by dike protection in the Westcott Cove area. Under this plan, a gated opening for navigation is provided through the barrier.

62. SELECTION OF PLAN OF PROTECTION

The following points were taken into account in eliminating a number of plans from detailed consideration early in the survey; also in arriving at the selection of Plan "E" as the one to be studied in detail.

a. Preliminary determinations of benefit to cost ratios indicated that the economic justification for Plan "E" was equal to or better than that for other plans. Many of the considered plans were determined to be uneconomical.

b. Considered barriers across the East Branch, with no openings for navigation, were objectionable to the city since they closed the Branch to navigation above the barrier site. Moreover, such plans would entail costs for the damages that would be sustained by commercial and industrial interests on the Branch that utilize present navigation facilities.

c. A barrier located near the mouth of the Branch creates a pool of sufficient storage capacity, when openings through the barrier are closed, to safely pond interior drainage without the need

for pumping facilities. At upstream sites, the available storage capacity is insufficient to permit ponding without any overflow of the banks.

d. The construction of barriers with navigation openings, at sites at or above the north end of Woodland Cemetery, would entail an interruption in navigation above the site during a construction period of about one year since no provisions can be made for a temporary bypass channel. The relatively narrow width of the Branch at upstream barrier sites precludes the dredging of a bypass channel.

e. Dike and wall protection along the banks of the upper half of the East Branch presents a problem to commercial and industrial interests in having to operate over protective works eight to nine feet above the levels of their wharves.

The cost of the considered alternate plan of protection calling for a barrier at the mouth of the East Branch, in the vicinity of Ware Island, exceeds that of the plan providing for a barrier crossing 1,000 feet above the mouth (Plan "E"). The additional cost cannot be justified by the additional benefits that would be realized.

Preliminary consideration of barrier protection at the entrance to the harbor, along the alignment of the breakwaters, revealed that the cost of such protection would be very high in comparison with benefits. The cost would be of a magnitude in excess of four times the amount of damages sustained in 1954.

In the Westcott Cove area, it was found that the additional cost of protection following an alignment along the shore, over the cost of protection along an alignment inland of the lagoon, would be considerably greater than the additional benefits that would be obtained. Damages along the west bank of the West Branch and the Noroton River were found to be insufficient to justify local protection works. Moreover, dike or wall protection along the west bank of the West Branch would interfere with the operation of waterfront terminals in this area.

HURRICANE FLOOD CONTROL PLAN

63. The analyses of various alternate plans indicated that Plan "E" promises the greatest probability of providing economically justifiable protection for the city of Stamford with minimum disruption to existing facilities.

64. GENERAL DESCRIPTION

The selected hurricane protection plan for Stamford, designated as Plan "E", consists of three structures, as shown on Plate 2 of this report. The principal feature of the plan is a barrier across the East Branch, near its mouth, to prevent the entrance of tidal surges up the Branch. Supplemental dikes and walls are provided along the West Branch and in the Westcott Cove-Cummings Park area of the city to prevent flanking of the East Branch protection. Borings recently obtained in the field indicate the site of the East Branch barrier to be a favorable one from a geological standpoint. Each phase of the plan is described below, with more detailed data contained in Appendix E.

65. EAST BRANCH BARRIER AND DIKES

a. Barrier. The proposed barrier consists of 1,030 feet of earth-filled dike, with rock faces and toes. It will extend across the East Branch at a point about 1,000 feet above its mouth - about 900 feet north of Ware Island. The barrier will have a top elevation of 18 feet msl, a top width of 20 feet, and side slopes of 1 on 2.5. A gated opening, 75 feet wide, is included in the barrier where it crosses the existing navigation channel.

b. Dikes. At the west end of the barrier, a dike extension, 370 feet long, will effect closure to high ground in Dyke Park just south of Woodland Cemetery. Closure to high ground at the east end of the barrier, near the intersection of Shippan Avenue and Wallace Street, is completed by a dike extension 1,040 feet long. The dikes will be of earth fill with rock on the seaward slopes and seeded topsoil on the landward slopes. They will have a top elevation ranging from 16 to 18 feet msl, a top width of 10 feet, and side slopes of 1 on 1.5 on the seaward side and 1 on 2.0 on the landward side.

c. Navigation Gates. Closure of the navigation opening in the barrier will be accomplished by sector gates with concrete abutments and sill founded on rock. Each gate has a radius of 46.2 feet, a central angle of 60 degrees, and a total height of 36 feet. The gate sills will be at an elevation of 18.0 feet below msl (14.6 feet below mlw). The navigation channel in the East Branch has an authorized project depth of 12 feet below mean low water and a controlling depth, in 1956, of 8 feet except for an area at 3.5-foot depth along the westerly edge that has not yet been dredged.

(1) Operation of the gates. The gates will be opened and closed by means of a rack and pinion drive. Controls will be arranged so that the gates can be operated singly or simultaneously, from either of the two control houses, one on each abutment. Normally, the gates will be in an open position with each gate set into a

recess in its abutment. The gates will be closed only when a hurricane is imminent, with the desirable time for closure being the period of slack water preceding a forecast rise in water level due to a hurricane or other severe storm.

(2) Current velocities. The average current velocity in the 75-foot wide navigation opening will peak at about 0.8 knot during the flood and ebb of a spring tide; and the maximum current at the center of the opening, near the surface, would be approximately one knot. A determination also has been made of the maximum current which can be expected through the opening at the time of a future hurricane equivalent to that of September 1938. This velocity was found to be less than 4 knots.

d. Temporary Bypass Channel. It is contemplated that the gate structure in the East Branch barrier will be constructed in the dry by the installation of a cellular cofferdam. To accommodate navigation during the period of construction, a temporary bypass channel will be dredged along the west shore of the Branch, around the cofferdam. A portion of the material removed in dredging of the bypass channel will be available for use as fill in the barrier and dikes.

e. Channel Widening or Realignment. The site of the gated opening for navigation is located at an angle in the alignment of the present 12-foot channel in the East Branch. In order to afford a straight approach to and through the opening, the angle will be eliminated by realigning the channel so that its east limit will pass through a point about 30 feet east of the present channel limit at the gate site. This widening also permits locating the center of the navigation opening 30 feet east of the center line of the present channel thereby providing additional area, west of the gate structure, for a temporary bypass channel during the construction period.

66. WEST BRANCH PROTECTION

This protection, located on the east bank of the West Branch, consists of 1,780 feet of concrete wall, 220 feet of sheet pile bulkhead wall, 1,810 feet of earth-filled dike or barrier, and a pumping station approximately 50 feet long. The dike is constructed with rock face on the top and seaward slope and either rock or seeded topsoil on the landward slope. Protection starts at high ground west of South Street and north of Atlantic Street, runs south to Atlantic Street, then follows approximately the north, west, and south property lines of the Hartford Electric Light Company to high ground at Dyke Park, east of Dyke Lane. The walls forming the northern or upper half of the protection have top

elevations ranging from 16 to 17 feet msl. The dike portion will have a top elevation ranging from 16 to 18 feet msl, a top width of 10 feet, and side slopes of 1 on 1.5 and 1 on 2.0 on the seaward side and 1 on 2.0 on the landward side.

Appurtenant structures consist of a 40,000 gpm pumping station, where the dike crosses the tidal inlet west of Dyke Park, and nine stoplog structures to provide access openings through the dike and walls. One stoplog is at the crossing of Atlantic Street; one affords access from Atlantic Street to the power company property; five, on power company property, afford access to wharf and other facilities outside the walls; one provides access to the shipyard south of the power company; and one is at the dike crossing of Dyke Lane. Three sluice gates will be installed at the outlets of cooling water discharge lines from the power plant of the Hartford Electric Light Co.

67. WESTCOTT COVE PROTECTION

This protection consists of 4,400 feet of earth-filled dike with rock facing on the top and seaward slopes and seeded topsoil on the landward slopes. The dike starts at high ground south of Iroquois Road, runs easterly for a distance of 600 feet to the easterly side of Wampanaw Road, then turns and runs in a general northerly direction for a distance of 2,700 feet to the entrance of Cummings Park, and then in a northeasterly direction for 1,100 feet, across the park, to high ground at the intersection of McMullen and Soundview Avenues. In the event of a design hurricane, one to two feet of sandbagging will be required to close off East Avenue and a swale area, about 100 feet wide, south of East Avenue and East of Soundview Avenue. Stoplog structures will be constructed at the dike crossing of Wampanaw Road, Rippowam Road, and the entrance to Cummings Park.

68. SEWER MODIFICATIONS

In order to prevent the backup of hurricane tidal-flood waters, tide-gate chambers will be installed in existing lines which carry sewerage from outside of the protected area to the treatment plant located within the protected area. Lines passing under project structures will be reinforced or replaced with heavier pipe where necessary. Manholes will be made watertight.

69. DRAINAGE MODIFICATIONS

All existing drainage lines passing under the dikes and walls will be strengthened or replaced in order to carry the added weight to which they will be subjected by reason of the protective structures. Where required, gates or flap valves will be installed to prevent the entry of tidal waters. To prevent the ponding of surface runoff

during periods of normal tide, catch basins will be constructed on the landward side of the West Branch and Westcott Cove protective works and necessary minor grading accomplished. An interceptor line, ranging from 42 to 54 inches in diameter, will be installed along South Street and Dyke Lane, south of Atlantic Street, to conduct interior runoff from the area north of Atlantic Street to the storage pond behind the pumping station.

70. LANDS AND RIGHTS-OF-WAY

Construction of the project will require the acquisition in fee of about 2.5 acres of land, permanent easements on approximately 10.5 acres, and temporary easement on 4.0 acres for the period of construction. A permanent right of access through Woodland Cemetery, over an existing road, will be required. The acquisition of one summer home is also contemplated. Further studies of alignment, however, during final design stages and prior to construction, may show the acquisition of this home to be unnecessary. Permanent easements, for the most part, will follow existing property lines. Land within easement areas, not actually occupied by protective structures, will be available for use by the owner. Approximately 40 percent of the land to be covered by permanent easement and 30 percent of that to be covered by temporary easement is now owned by the city of Stamford.

71. HYDROLOGIC AND HYDRAULIC CONSIDERATIONS

The proposed protective structures will be constructed to meet conditions imposed by a design hurricane, i.e., a surge of 10.4 feet on top of a maximum spring tide and significant waves up to 4 feet in height. In developing the plan of protection, consideration has been given to the following:

a. Runup and overtopping of structures by storm waves.

b. Ponding behind dikes and walls.

c. Buildup in the pool behind the protective works, from interior drainage and/or overtopping, when all gates and openings are closed.

d. Current velocities through the navigation opening in the barrier.

Design storm and runoff data are discussed in paragraphs 39 and 42 of this report and in Appendix B. Appendix B also presents data on other hydrologic and hydraulic factors that have been considered in the design of protective works.

72. PONDING AND POOL BUILDUP

At the time of a hurricane, when all openings through the barrier, dikes, and walls are closed to prevent the entry of hurricane tidal-flood waters, ponding will result behind the protective works. The degree of ponding will depend on the volume of runoff from coincident rainfall and on the amount of overtopping by hurricane waves.

An examination of historical records indicates that past hurricanes which have caused heavy precipitation along the Connecticut coast have not caused serious tidal flooding, and conversely, that hurricanes which have caused disastrous tidal flooding have not produced unusually heavy rains. In other words, it appears that the conditions contributing to a high surge, such as were experienced in the hurricane of September 1938, i.e., a fast-moving storm and high winds, are not conditions conducive to heavy precipitation such as experienced during Hurricane "Diane" in August 1955. Therefore, it is considered that conditions of a design rainfall coinciding with those of a design hurricane surge will be very rare.

The estimate for Plan "E" includes a 40,000 gpm pumping station in the West Branch protection, at the dike crossing of the tidal inlet west of Dyke Park, to reduce the amount of ponding behind this protection. Detailed hydrology and hydraulic studies in the final design stage may indicate that it would be desirable from an economic viewpoint to omit this station and permit ponding to occur. The anticipated degree of ponding behind the East Branch protection and the Westcott Cove dike is not considered to present a serious enough problem to warrant the provision of pumping facilities.

a. West Branch Protection. The selected capacity of the pumping station included in the West Branch protection has been predicated on handling the storm drainage discharge that could be brought to the station through existing lines and the proposed new interceptor running south from Atlantic Street. With a recurrence of 1938 and 1954 hurricanes, no ponding would occur in the area behind the dikes and walls by reason of interior runoff and overtopping. There would be no overtopping in a recurrence of the 1944 hurricane and the October 1955 storm but ponding from interior drainage would be experienced to depths of 0.2 and 2.6 feet, respectively, resulting in ponding levels of 2.7 and 5.1 feet msl. This would be in the depressed area of the South End at Pacific and Crosby Streets.

Under the conditions of a design hurricane, overtopping would contribute 40 acre feet of water to the area behind the protective works. Assuming that all of the overtopping found its way to the low area at Pacific and Crosby Streets, this would result in ponding to an elevation of 5.3 feet msl in this area, with no pumping. Design rainfall, equal to that experienced in the October 1955 storm, would alone give ponding to an elevation of 5.1 feet msl with Plan "E" in operation. The combination of these two conditions is extremely improbable. Overtopping in a design hurricane together with runoff from a rainfall approximately equivalent to that of the 1944 hurricane (3.9 inches in 12 hours) gives ponding to about 5.4 feet msl. Zero damage in the low area of the South End starts at elevation 3.5 feet msl; significant damage (in excess of $100,000) starts at a stage of about 6.3 feet msl.

b. East Branch Protection. Studies of the buildup in the pool behind the East Branch barrier, from ponding of runoff or overtopping, during the time that gates in the barrier are closed, indicate ponding as tabulated below for hurricanes and storms of varying intensities:

Hurricane or Storm	Volume of Ponding (ac.-ft.)	Duration (hours)	Rise in Pool Level (feet)	Cause
Sep 1938	86	7.8	2.0	Runoff
Aug 1954	82	8.0	1.9	Runoff
Sep 1944	255	7.5	5.0	Runoff
Oct 1955	375	7.0	6.6	Runoff
Design	189	3.0	3.9	Overtopping

Overtopping in a design hurricane, plus the runoff from a rainfall equivalent to that experienced during the 1944 hurricane, would result in the ponding of 444 acre feet and give a rise in the pool of 7.4 feet. This latter figure is believed to represent a fair value of the extent of ponding that can be experienced in the event of a design hurricane. With the navigation gates closed at a time when the water in the Branch is at mean sea level, the rise in pool levels tabulated above represents elevations in feet above mean sea level. Damage in the East Branch starts at an elevation of 6.3 feet msl, or 4.0 feet below the 1954 flood stage. Significant damage (in excess of $100,000) starts at an elevation of about 8.3 feet msl.

c. Westcott Cove Protection. Only minor ponding will occur behind the Westcott Cove dike in the event of a future hurricane or storm equal in magnitude to those that have occurred during the

past 50 years. Ponding under such conditions would result entirely from interior drainage. Runoff from the 113-acre drainage area behind this dike will create ponding to an elevation of less than 7.3 feet msl, at the foot of Rippowam Road, with a recurring 1944 hurricane rainfall and to an elevation of about 7.5 feet msl with a recurring rainfall equal to that experienced in the October 1955 storm. Ponding behind the dike from overtopping in a design hurricane will also be negligible. Damage from ponding behind the Westcott Cove dike begins at an elevation of about 7.3 feet msl at the foot of Rippowam Road. Damage in excess of $10,000 is experienced when the ponding reaches an elevation of about 9.0 feet msl.

73. DEGREE OF PROTECTION

Plan "E" affords complete tidal-flood protection to about 460 acres of property in the city of Stamford, below an elevation of 11.0 feet msl, that were inundated by flooding in the hurricanes of 21 September 1938 and 31 August 1954. This represents protection to an area in which nearly ninety percent of the total damages were sustained although geographically it covers only about one-half of the entire flooded area. With a recurring storm equivalent to that experienced in October 1955, ponding of runoff would be experienced to an elevation of about 5.1 feet msl in the low area of the South End at Pacific and Crosby Streets. This ponding, which would cause damages of approximately $10,000, is due to inadequate pumping and drainage facilities to handle the runoff and is outside the scope of hurricane protection.

Plan "E" also affords a very high degree of protection in the event of a design hurricane, with a stillwater flood level of 16.0 feet msl, combined with rainfall as experienced in the 1944 hurricane. Upon such an occurrence, overtopping of the West Branch protection by hurricane waves plus runoff would create ponding to an elevation of 5.4 feet msl in the low area at Pacific and Crosby Streets. Flooding to this elevation - a maximum depth of 2.9 feet over the ground - is equivalent to a damage of about $20,000. However, it also represents a reduction of 10.6 feet in the level of flooding that would occur if no protection is provided.

Ponding behind the East Branch protection, with a design hurricane and 1944 hurricane rainfall, would reach an elevation of about 7.7 feet msl, approximately one foot above the stage at which damage begins, providing the navigation gates in the barrier are closed when the tide is at a mean sea level stage. If closure of the gates were delayed until the tide was at mean high water, ponding in the pool above the barrier would reach an elevation about two feet above the stage of zero damage and cause damages of over $100,000. No ponding of consequence would be experienced behind the protective works in the Westcott Cove-Cummings Park area.

74. EFFECT OF PLAN ON HARBOR INTERESTS

The effects of hurricane protection Plan "E" on the various interests concerned with the use of the harbor and waterfront areas at Stamford are discussed in the following paragraphs.

a. Navigation. Hydraulic studies indicate that the East Branch barrier, with navigation opening, will have no measurable effect on the range of tide in the Branch. Therefore, there will be no reduction in the depth of water available to vessels that are dependent on the tide for navigation in the East Branch. The maximum current of one knot that would be experienced in the opening, at the time of a spring tide, will have a negligible effect on present or prospective vessel traffic. The opening is in a relatively sheltered location in Stamford Harbor that is not subject to high currents and waves.

An objection to the selected 75-foot width of opening has been raised by a representative of towboating interests and the suggestion made that the opening have a minimum width of 90 feet to permit the passage of a tug with a barge alongside. (See Appendix F). Although this is one feasible manner for a tug with a barge to navigate an opening, there is no apparent reason why passage could not be accomplished safely by use of a short hawser between the tug and barge. There are a number of openings in New England, 50 to 70 feet wide, in bridges crossing improved channels of greater dimensions than the East Branch channel, that are safely navigated by a tug with a barge. The largest vessel entering the East Branch at the present time is a barge with a beam of about 40 feet and a length of 240 feet. The proposed width of 75 feet in the opening is considered to be sufficient to accommodate this barge. Barge traffic should encounter no appreciable delays in entering or leaving the Branch through this opening.

The proposed elevation of 18.0 feet, msl, (14.6 feet mlw) for the gate sill is 2.6 feet below the present authorized channel depth of 12.0 feet and 6.6 feet below the present controlling depth of 8.0 feet. This sill elevation is considered adequate to meet the needs of anticipated future commercial navigation in the Branch. No expressions of need or desire for a lower sill elevation have been voiced by shipping or local interests.

The barrier across the East Branch will also provide a refuge in the Branch for recreational craft and other vessels at times of a hurricane or other severe storm. It should tend to encourage increased use of the harbor area by recreational craft. Moreover, it will obviate the need for tugs to remove barges from alongside East Branch wharves in order to prevent damage to the barges at times of hurricane high waters.

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b. Pollution. Federal and state health authorities have considered the effect of the barrier on pollution in the East Branch. They have concluded that the plan will not adversely affect sanitary conditions in the branch since there will be no appreciable change in the tidal regimen above the barrier.

c. Fish and Wildlife. Federal and state fish and wildlife interests have concurred in the opinion that protection Plan "E" will not be detrimental to the fishing resources of the area. (See Appendix F.)

d. Recreation. The selected plan of protection will have no adverse effect on the present recreational activities of the area. The barrier will render the harbor more desirable as a home port and afford a sheltered haven for craft cruising in the Sound.

e. Industry. The adoption of Plan "E" will not require the removal of any industrial building or cause curtailment of present industrial activities. The thermal electric generating plant now using salt water for cooling purposes will continue to do so.

75. EFFECT OF PLAN ON ADJACENT SHORELINE

The East Branch barrier in the selected plan of hurricane protection for Stamford (Plan "E"), owing to its location, will not cause accretion or erosion along the adjacent shorelines.

ESTIMATES OF FIRST COSTS AND ANNUAL CHARGES

76. The estimated total first cost of the project, based on 1957 prices is $5,586,000. This includes allowances for engineering and design, and supervision and inspection during construction. Adding the cost. Adding the cost of aids to navigation, preauthorization studies, and interest during construction for one-half a construction period of two years, gives a total investment of $5,791,000. Total annual charges amount to $248,000. This includes interest at a rate of 2.5 percent, amortization over a 50-year project life, and an allowance of $43,000 for annual operation and maintenance, including a charge to cover the cost of major replacements in the future.

A summary of the first cost and annual charges is shown in Table 5 on the following page. The figures in the tabulation are based on local interests furnishing all required lands, easements, and rights-of-way at an estimated cost of $150,000; accomplishing all necessary modifications to the present sanitary and storm-drainage facilities at an estimated cost of $120,000; operating and maintaining all the land features of the project, including the pumping station located at the inlet west of Dyke Park; and contributing an amount presently estimated at $2,286,000, equivalent to 40.9 percent of the total first cost. See paragraphs 81 and 82. Additional data, including a breakdown of quantities and unit prices, are contained in Appendix E.

ESTIMATES OF BENEFITS

77. TANGIBLE BENEFITS

Evaluated benefits to Plan "E" include those attributable to (1) the prevention of tidal-flood damages, (2) the elimination of scare costs, and (3) the increased utilization or enhancement of property. The average annual benefits from the prevention of tidal-flood damages have been estimated at $337,000. This amount equals the difference between a total average annual loss of $378,000 in the protected area and an average annual residual loss of $41,000 remaining after protection is provided. These losses are based on damage-frequency data obtained by combining stage-loss and stage-frequency information. The residual loss of $41,000 represents damages that would be experienced with flooding, of very rare frequency, above the design stage of 16 feet msl.

Scare costs, see paragraph 48, amount to $44,000 for each scare. On the basis of four warnings or scares every ten years, the annual cost due to scares equals $17,000, which would be eliminated if protection is provided.

Enhancement benefits, those attributable to the increased or higher utilization of property made possible through the provision of protection, would result largely from industrial expansion and construction of industrial parking lots and a municipal heliport on lands that were formerly only partially developed due to the

TABLE 5

FIRST COSTS AND ANNUAL CHARGES

HURRICANE PROTECTION PLAN "E"

Stamford, Connecticut

Item	Federal	Local	Total
		First Cost and Investment	
Construction of Barriers, Dikes and Walls	$3,030,000	$2,286,000(1)	$5,316,000
Modifications to Sanitary and Storm Drainage Facilities	---	120,000	120,000
Lands and Damages	---	150,000	150,000
Total First Cost	$3,030,000	$2,556,000	$5,586,000
Aids to Navigation (2)	14,000	---	14,000
Preauthorization Studies	50,000	---	50,000
Interest during Construction	77,000	64,000	141,000
Total Investment	$3,171,000	$2,620,000	$5,791,000
		Annual Charges	
Interest on Investment	$ 79,000	$ 66,000	$ 145,000
Amortization	33,000	27,000	60,000
Operation and Maintenance	32,000(3)	11,000(4)	43,000
Total Annual Charges	$144,000	$104,000	$248,000

(1) Includes cash contribution (presently estimated at $1,406,000) equivalent to 30% of project first cost (0.3 x $5,586,000), less credit ($270,000) for furnishing lands, etc. and accomplishing sewerage and drainage modifications; plus an additional amount (presently estimated at $880,000) equal to the capitalized value of the annual cost for operation and maintenance of the East Branch barrier, and gate.

(2) Installation by U.S. Coast Guard.

(3) $31,000 for East Branch barrier and gates, including $2,000 for major replacements; plus $1,000 for aids to navigation.

(4) Includes $1,000 for major replacements.

hazards of floods. The enhancement of property values that would be obtained at Stamford, with protection provided, has been estimated at $150,000. Capitalized at six percent this gives an annual benefit of $9,000.

The total evaluated annual benefits creditable to Plan "E" are summarized below:

Item	Average Annual Benefit
Prevention of flood damage	$ 337,000
Elimination of scare costs	17,000
Enhancement	9,000
Total	$ 363,000

In the determination of benefits, no consideration has been given to the indicated rise in sea level as revealed by recent investigations of the U. S. Coast and Geodetic Survey. See paragraph 36. If mean sea level continues to rise during the life of the project, greater damages can be anticipated from flooding caused by hurricane surges.

Westcott Cove constitutes one possible source of material for use in construction of dikes. If dike fill is obtained from the channel in Westcott Cove, the increased depth secured by the dredging will serve to extend the time when maintenance dredging will be required and thereby reduce the annual cost of maintenance for a number of years. It has been estimated that a three-foot increase in depth would eliminate the need for maintenance dredging for 20 years and save a total of $30,000 in dredging costs, an average of $1,500 a year for the first 20 years of the life of the hurricane project.

78. UNEVALUATED TANGIBLE BENEFITS

In the computation of benefits it has been impractical to include some of the losses resulting from tidal flooding. Among these, the most significant is the losses to recreational craft and commercial vessels afloat and to automobiles parked on public highways and in commercial parking lots. The average annual benefits do not reflect the prevention of losses in this category.

79. INTANGIBLE BENEFITS

The intangible benefits derived from the construction of adequate protective works in the survey area are of considerable importance. Loss of life would be prevented, and the dangers of

disease arising from polluted flood waters would be eliminated. Insecurity and worry among the residents concerning unpredictable hurricane flooding would be greatly reduced. Protection would undoubtedly stimulate all segments of the economy and improve the general welfare of the residents.

ECONOMIC JUSTIFICATION

80. A comparison of annual charges of $248,000 with evaluated annual benefits in an amount of $363,000 gives a benefit-cost ratio of 1.5 to 1 for Plan "E".

PROPOSED LOCAL COOPERATION

81. The hurricane protection plan considered for the city of Stamford is similar in nature to a local flood-control project. Therefore, it is considered reasonable to require as a minimum degree of local participation the cooperation that is presently required under existing law for local projects providing protection against fresh-water flooding. On this basis, local interests in Stamford would be required to cooperate to the following extent:

a. Provide without cost to the United States all land, easements, and rights-of-way necessary for construction of the project.

b. Hold and save the United States free from damage due to the construction works.

c. Maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of the Army.

The East Branch barrier in Plan "E" crosses a Federal navigation improvement, and operation and maintenance of this barrier and its gates must be accomplished with the needs of navigation in view. Proper timing of gate-closing operations upon the occurrence of a hurricane is essential in obtaining the maximum possible benefits from the reduction of tidal-flood levels in the Branch above the barrier. Therefore, it appears that operation and maintenance of the East Branch barrier and gates are of sufficient importance to warrant the performance of these functions by the Federal Government. However, since this is a responsibility that should be assumed by local interests, they should bear the cost of such work. This can be accomplished by means of a local cash

contribution in an amount presently estimated at $880,000. This contribution is equivalent to the capitalized value of the estimated Federal annual cost for operation and maintenance of the portion of the East Branch protective works located in tidal waters. Annual operation and maintenance of all other features of the plan, including the pumping station, dikes and walls along the West Branch and protective works in the Westcott Cove-Cummings Park area, will be a local responsibility.

In addition to the minimum requirements set forth above, it is proposed that local interests share in the first cost of the project to the extent of contributing in cash an amount presently estimated at $1,406,000. This amount, subject to final determination upon completion of construction, is equivalent to 30 percent of the total first cost, with credit allowed for the costs incurred by local interests for furnishing lands, easements, and rights-of-way and accomplishing necessary modifications to sewerage and drainage facilities and relocations of utilities and structures. See Table E-3, Appendix E.

No definite offers of cooperation were advanced by local interests at the public hearing held 12 February 1958. They did indicate an awareness of the fact that cooperation would be required. No objections were voiced. Subsequent to the hearing, expressions of willingness and ability to comply with the above provisions of local cooperation have been received from responsible elected officials of Stamford and the State of Connecticut. See Appendix F.

APPORTIONMENT OF COSTS AMONG INTERESTS

82. A breakdown of the total first cost, investment, and annual charges for Hurricane Protection Plan "E", between Federal and non-Federal interests, is shown in Table 5. The figures in this table are predicated on local cooperation to the extent set forth in paragraphs 76 and 81 above, with local interests making a cash contribution to the first cost.

The total first cost of the project is estimated at $5,586,000. This includes local cost estimated at $120,000 for modifications to sanitary and storm drainage facilities and $150,000 for the acquisition of lands and rights-of-way, or a total of $270,000. With a cash contribution to the first cost of the project in an amount presently estimated at $2,286,000 ($1,406,000 plus $880,000), the total local first cost becomes $2,556,000 and the Federal first cost $3,030,000.

The total annual charges for the project are estimated at $248,000. The Federal portion is $144,000 and the local share $104,000 or about 42 percent of the total.

COORDINATION WITH OTHER AGENCIES

83. In the course of this survey, assistance and cooperation have been received from Federal, state, and local agencies, that are concerned with hurricane activities, or are particularly interested in the hurricane protection problem at Stamford. Meetings have been held with representatives of these agencies for the purposes of discussing the proposed plan of protection and alternative plans, determining the effect of the plan on other interests concerned with development and use of the water and other natural resources of the locality, and ascertaining the relationship between the proposed hurricane protection plan and the plans of other agencies for improvements within the survey area.

The U.S. Weather Bureau has furnished information on the behavior and characteristics of hurricanes and data on maximum wind velocities and durations that may be anticipated in the future. The effect of the proposed harbor barrier on pollution has been discussed with the Public Health Service of the U.S. Department of Health, Education and Welfare and with the Connecticut State Water Resources Commission. These two agencies concur in the opinion that the hurricane protection plan will not result in adverse sanitary conditions in the inner harbor. Coordination also has been maintained with the State Water Resources Commission with a view to determining the needs of navigation and correlating the plan of protection with these needs. The Fish and Wildlife Service of the U.S. Department of the Interior and the Connecticut State Board of Fisheries and Game have considered the barrier plan and state that it would not have an adverse effect on the fishing resources of the area.

Informal meetings and conferences have been held with municipal officials of Stamford and representatives of Stamford commercial and industrial interests to obtain their views and comments on the proposed plan and other plans that have been given consideration, and to keep local interests advised of the progress being made on the survey. Considerable assistance has been rendered by city officials, representatives of local industrial concerns and the power company, and the Stamford-Greenwich Manufacturers' Council.

DISCUSSION

84. THE PROBLEM

The city of Stamford has experienced very heavy tidal-flood losses in recent hurricanes and other great storms. The cities and towns along the Connecticut coast, including Stamford, although not situated on the open ocean, are subject to flooding from hurricane surges that travel up Long Island Sound from its eastern entrance off Montauk, Long Island. A recurring September 1938 hurricane would cause tidal-flood losses in Stamford of approximately $5,790,000; a recurring September 1944 hurricane, losses of $620,000; and a recurring 1954 hurricane, losses of $3,050,000. Future storms, other than hurricanes, equal in severity to those experienced in November 1950 and November 1953 would cause damages equivalent to or slightly greater than those that would be experienced in a recurring 1944 hurricane. The need for protection has become urgent, particularly in the South End, a low-lying area between the East and West Branches at the head of Stamford Harbor, which experienced damages of nearly $2,500,000, or 75 percent of the total in Stamford, during the 1954 hurricane. A design hurricane, representative of future potential attacks, derived by transposing the 1944 hurricane, a storm of unusual energy off Cape Hatteras, to a track over water and timed to cause the surge to strike Stamford coincident with a spring tide, is capable of causing over three times the tidal-flood damages that would be sustained in a recurring 1938 hurricane. It is obvious that protective measures are needed to safeguard the major damage areas of the city from flooding caused by future hurricanes and other storms.

85. ALTERNATIVE SOLUTIONS

Some reduction in hurricane tidal-flood damages can be effected by the provision of improved forecasting and warning services, the establishment of programs for the evacuation of danger areas, the enactment of revised zoning ordinances, and the adoption of modified building codes. Improved warning facilities and plans for evacuation, although effective in reducing loss of life and damage to items which are readily movable, do not prevent the actual flooding of properties and are of only relatively little value in preventing damage. The costs incurred by relocation and rezoning would be prohibitive in the thickly developed industrial and urban areas of Stamford which are subject to tidal flooding. The valuation of the industrial property involved is many times the cost of protection or the amount of damages. Moreover, any extensive relocation would disrupt the entire economy of the city. A positive means of protection which will eliminate the threat of future flooding to existing properties is required.

86. SELECTION OF PLAN

Nine different plans of protection by means of dikes, walls, and barriers have been considered together with several variations entailing minor modifications in a number of these plans. All of the plans considered are based principally on protection for the South End where the most severe damages have been experienced in the past. One plan would afford protection for practically the entire city by means of a barrier across the entrance to the main harbor area. All other plans provide for dike and wall protection along the east bank of the West Branch; and all but three call for protection in the Westcott Cove-Cummings Park area. Eight of the plans provide protection against flooding from the East Branch by means of dikes and walls alone or in conjunction with a barrier across the East Branch at one of five locations. The plan found most feasible, designated as Plan "E", provides for (1) a barrier, with a gated navigation opening, across the East Branch, at a point about 1,000 feet above its mouth; (2) dike extensions effecting closure to high ground at both ends of the barrier; (3) dike and wall protection on the east bank of the West Branch; and (4) dike protection in the area of Westcott Cove and Cummings Park. These works are designed to afford protection to a stillwater flood level of 16 feet msl, the level that would be reached in the event of a design hurricane. This flood level is 5.0 feet above the elevation of flooding experienced in the severe hurricane of September 1938.

87. EFFECTS ON OTHER INTERESTS

The proposed project would have no adverse effects on pollution or on fish and wildlife. Construction of the barrier would cause little or no change in the tidal regimen in the East Branch above the barrier site. Although an objection to the selected width of navigation opening has been raised by towboat interests, a width of 75 feet in the opening is considered to be sufficient to meet the needs of present and prospective vessel traffic. A preliminary estimate indicates that widening of the opening to 90 feet would increase both the first cost and annual cost of the project by nearly 10 percent, and decrease the ratio of benefits to costs by about the same percentage, from a ratio of 1.5 to 1.0 to 1.3 to 1.0. The expenditure of this additional amount to secure a wider opening for the approximately 300 round trips a year that are made by tug and barge to wharves on the East Branch does not appear to be justified. Moreover, no marked increase in commercial traffic is expected in the future. There are no known plans for future use of the Branch other than by shallow draft barges. Should the development of additional deep draft facilities prove desirable at Stamford, there are other areas along the waterfront, outside of the East Branch protection, which appear to be more suitable for

such development. If there is any increase in the future traffic in the East Branch, it will probably stem from recreational boating activity which has been increasing rapidly along the New England coast. The dimensions of the proposed gate in the East Branch barrier are more than ample to accomodate traffic of this nature. The barrier across the Branch will create a safe refuge in the Branch for recreational craft and other vessels at times of severe storms.

The maximum current of one knot that would be experienced in the navigation opening is not considered to be excessive from a navigation viewpoint. Four temporary lights to mark the bypass channel during the period of construction will be installed in accordance with recommendation of the U.S. Coast Guard. Also, necessary aids to navigation will be installed on the gate structure. Barge traffic should encounter no appreciable delay in entering or leaving the East Branch through the 75-foot wide opening in the hurricane barrier. The gate sill is at sufficient depth to permit the future deepening of the channel by 2.6 feet, to a depth of 14.6 feet below mean low water, without the need for modification to the gates or gate structure in the event this future improvement may be found necessary or desirable. However, future modification to this extent does not appear probable. The present controlling depth of eight feet is meeting the navigation needs of commercial interests along the Branch. Also, past surveys reveal rock at numerous locations at depths of 13 feet below mlw. The presence of rock at this depth makes it very unlikely that there will be any future channel improvement beyond the present authorized dimensions.

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88. COSTS

The first cost of the project, including the cost of lands, easements, and rights-of-way, and modifications to the existing sewerage and storm drainage facilities, is estimated at $5,586,000. The annual charges are estimated at $248,000.

89. BENEFITS

The average annual benefits to be obtained from the protection provided by Plan "E" are estimated at $363,000. This includes $337,000 derived from the elimination of flood damages, $17,000 from the elimination of scare costs, and $9,000 from land enhancement benefits. The benefit-cost ratio of the project is 1.5 to 1.0.

CONCLUSIONS

90. It is concluded that the city of Stamford, Connecticut, has sustained heavy damages in the past due to the flooding caused by hurricanes and other great storms and faces the continuing threat of similar damages in the future. It is further concluded that protection against tidal flooding can be attained most suitably through the construction of Plan "E" protective measures at a first cost of $5,586,000. This plan, which affords Stamford a high degree of protection, is amply justified, having a benefit to cost ratio of 1.5 to 1.0.

RECOMMENDATIONS

91. It is recommended that a plan of hurricane protection for Stamford, Connecticut, in accordance with the provisions of Plan "E" described in this report, consisting principally of a barrier across the East Branch, near its mouth, with a gated opening for navigation and dike extensions, dike and wall protection on the east bank of the West Branch, and dike protection in the Westcott Cove-Cummings Park area of the city, be authorized for construction. The presently estimated first cost to the United States is $3,030,000. The annual cost, for operation and maintenance of the East Branch barrier, and gate is $31,000.

It is further recommended that the project be authorized subject to the conditions that local interests cooperate to the following extent:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of the project, the costs incurred to be credited to the required local cash contribution to the project first cost.

b. Hold and save the United States free from damages due to the construction works.

c. Accomplish all modifications to the existing storm-drainage system which may be required to obtain the full benefits of the protection plan; make all necessary modifications to the existing sanitary sewer facilities required to prevent the entry of tidal-flood waters; and accomplish, without cost to the United States, all changes, alterations, additions to, or relocations of any buildings and utilities made necessary by reason of construction of the project; the costs incurred to be credited to the required local cash contribution to the project first cost.

d. Operate and maintain all features of the project after its completion, with exception of the portion of the East Branch protective works located in tidal waters, in accordance with regulations prescribed by the Secretary of the Army.

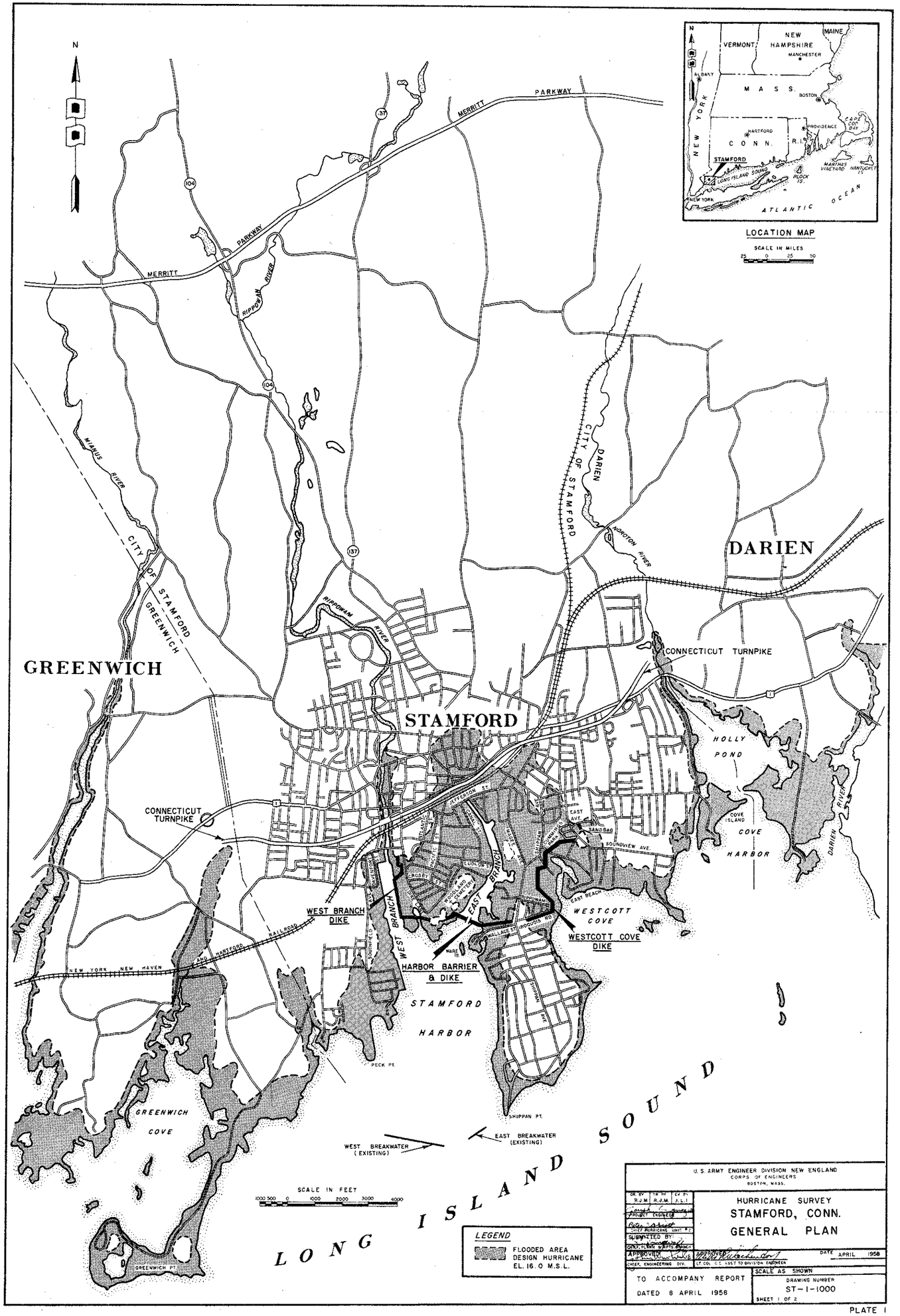
e. Contribute in cash an amount, presently estimated at $1,406,000, equal to 30 percent of the first cost, with credit allowed for the costs incurred in fulfilling local cooperation requirements 'a' and 'c' above.

f. Contribute in cash an amount, presently estimated at $880,000 equal to the capitalized value of the annual cost to the United States for operation and maintenance of the East Branch barrier and gate.

ALDEN K. SIBLEY
Brigadier General, U.S. Army
Division Engineer

Inclosures: (2)
1. Plate 1 - General Plan
   File No. St-1-1000
2. Plate 2 - Protection Plan "E"
   File No. St-1-1001

R. 2-9-59



U.S. ARMY ENGINEER DIVISION NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

DR. BY	TR. BY	CK. BY
R.J.M.	R.J.M.	J.L.I.

PROJECT ENGINEER
CHIEF HURRICANE UNIT, P.E.
SUBMITTED BY:
CHIEF, PLANS & SURVEYS BRANCH
APPROVED:
CHIEF, ENGINEERING DIV.
APPROVED:
LT. COL., C.E. ASST. TO DIVISION ENGINEER

HURRICANE SURVEY
STAMFORD, CONN.
GENERAL PLAN

DATE APRIL 1958

TO ACCOMPANY REPORT
DATED 8 APRIL 1958

SCALE AS SHOWN

DRAWING NUMBER
ST-1-1000

SHEET 1 OF 2

PLATE 1

CORPS OF ENGINEERS U. S. ARMY

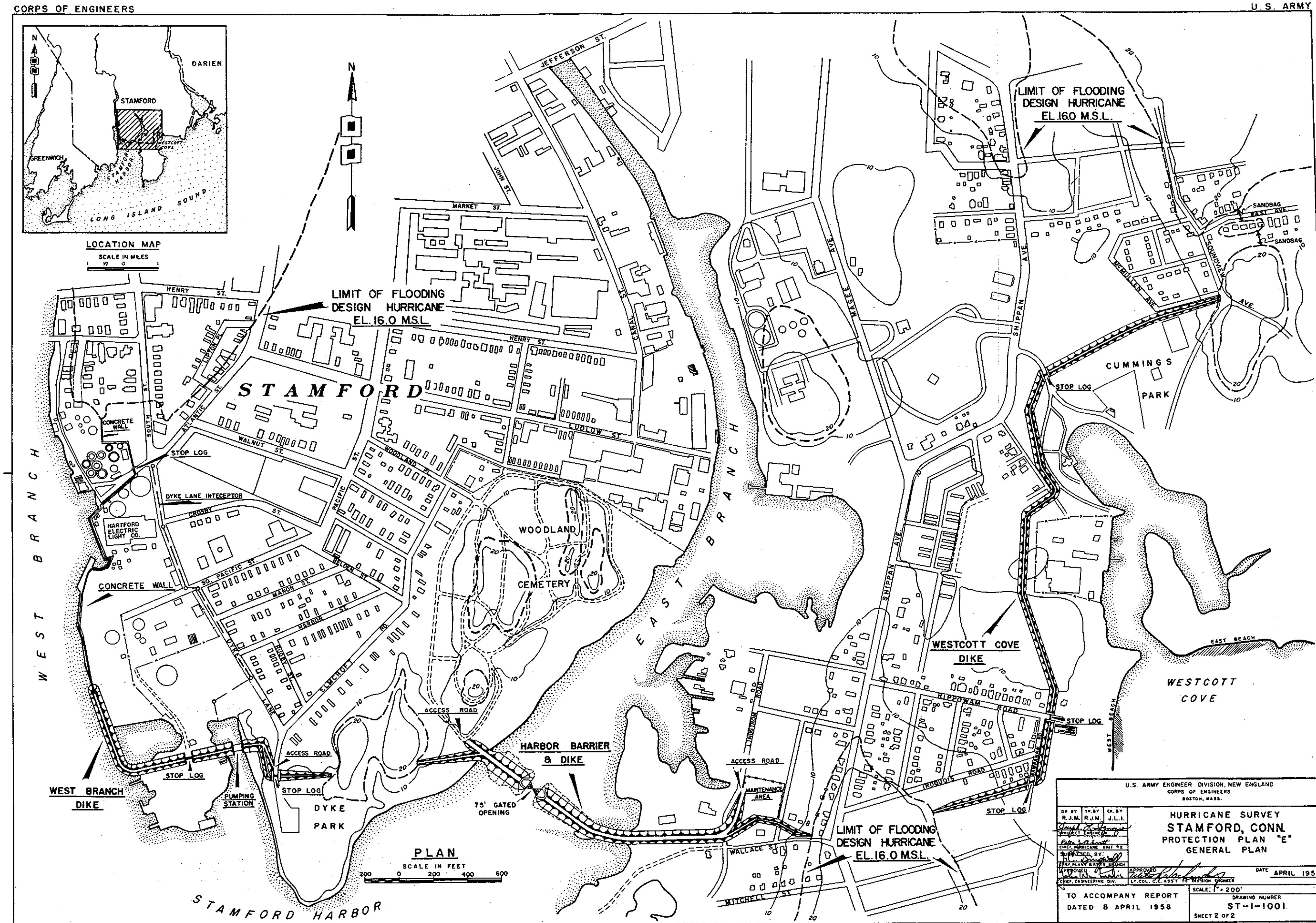


PLATE 2